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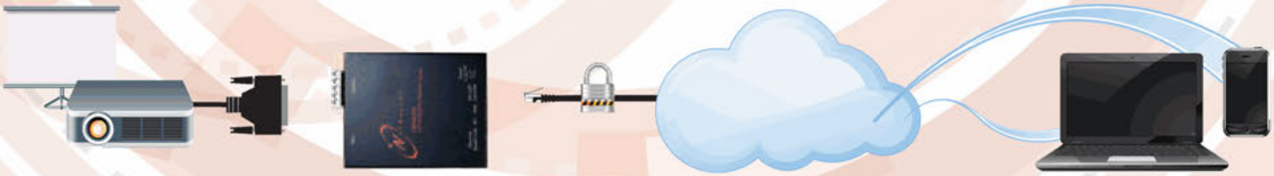

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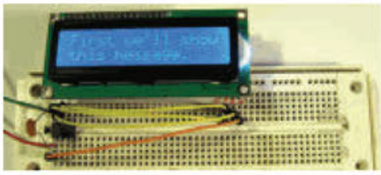

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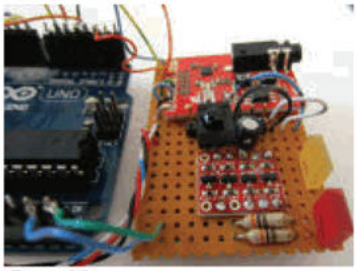

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Columns

Departments

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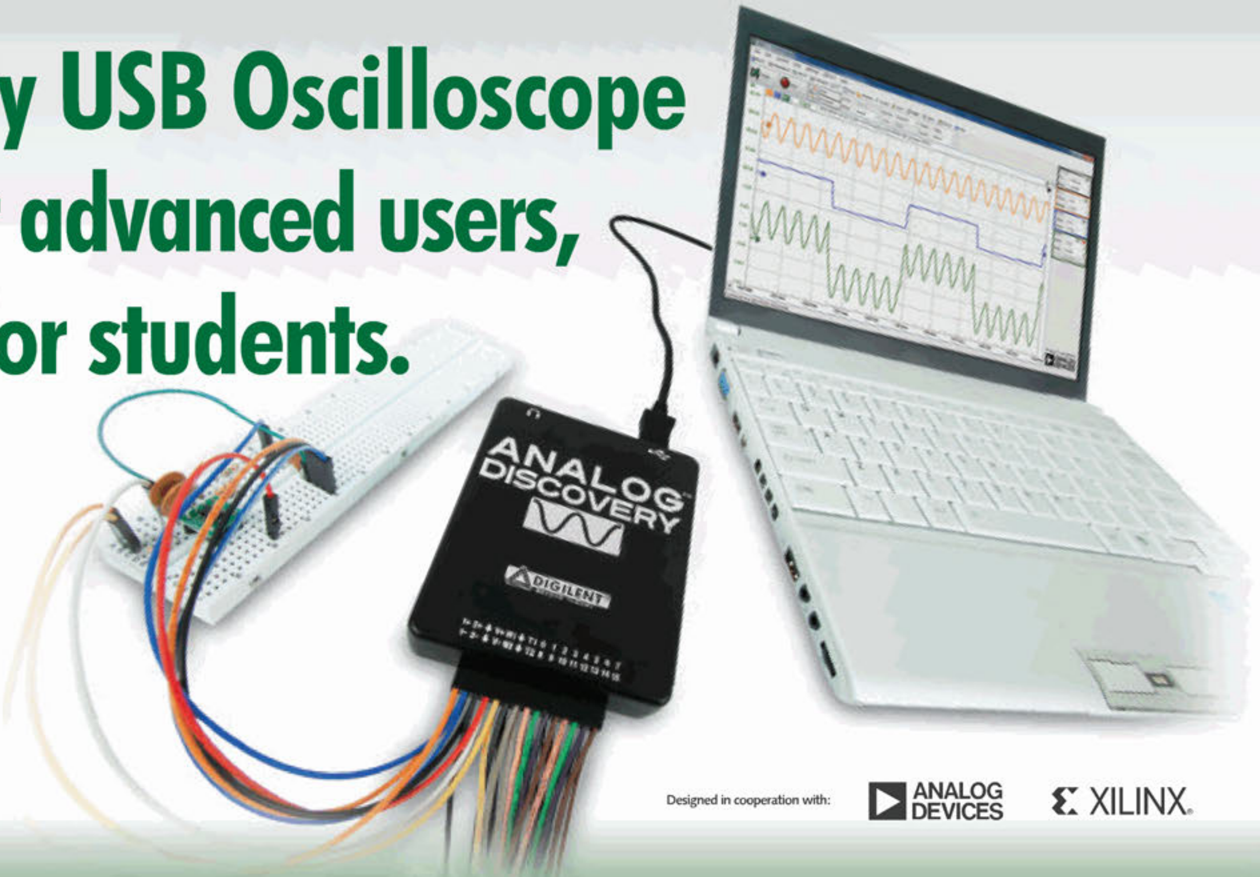
ANALOG DISCOVERY
DIGILENT

by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

Night Meeting

When Google announced that it had purchased Boston Dynamics, I couldn't help but think of Ray Bradbury's tale of Night Meeting, from his *Martian Chronicles*. The story begins when a man from Earth and a Martian encounter each other on a desolate road one night on Mars. The man is driving an old pickup truck, while the Martian is driving a multi-legged vehicle. They look out on the landscape and realize that they come from different times, but they can't determine which of them is from the future and which is from the past.

There's a lot more to the story, of course, but the metaphor of legged and wheeled vehicles passing in the night seems relevant to the Google-Boston Dynamics deal. Of course, Google is the company behind the driverless car that promises to make the steering wheel as useful as your appendix. Then, there's Boston Dynamics, the creator of the Army Mule, Big Dog, Cheetah, and other four-legged robots that can manage rough terrain that would stop a wheeled vehicle in its tracks. If you check out the Army Mule on YouTube, you'll hear that the gas-powered engine needs a bit of muffling before it can be used in a stealth operation, but otherwise, it seems up to the task of hauling gear.

I don't see multi-legged vehicles replacing the four-wheeled car any time soon, but cars aren't the only vehicles in use today. More and more "personal" vehicles are making their way onto sidewalks, in stores, and in the malls. These motorized carts and wheel chairs often require the user to detour onto ramps because they can't navigate steps or escalators. Perhaps there's something in a multi-legged vehicle that would provide value over and above the transportation provided by an ordinary motorized buggy.

For military purposes, there's the obvious advantage of a pack mule that can carry heavy loads and, eventually, serve as a vehicle for soldiers. For the soldiers who lose one or both legs in battle, riding a weaponized robotic mule into battle might be one way to contribute to the fight. For civilian purposes, imagine the spinoffs of the legged technology — from chairs that gently raise or lower an elderly or injured person, to walking assistants that either carry or guide the person to their destination.

One thing's for certain — we're bound to see spinoffs of the technology appear at our favorite online suppliers. I can't wait to get my hands on what I can only imagine is the sensor technology used by the Mule to maintain balance. Then, there's the camera system used to track the terrain. I don't know what sort of gasoline-powered generator is used in the Mule, but I'm sure that I can think of ways to repurpose the technology for other projects.

For now, I have no desire to be transformed into a bionic Centaur, but in another 30 years or so when my joints are arthritic from all those marathons, I may have a different opinion. It's good to have options, and that's certain to come from the Google-Boston Dynamics venture. **NV**

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READER FEEDBACK

Pleased With Project

Referring to the "Quick and Easy USB Keyboard Input" project by William Pippin in the November 2013 issue: This is a very useful and absolutely GREAT project idea! I put it together and it operates exactly as author-advertised. There's immediate response for use when it's plugged in and it works without a flaw on any pre-installed or user program that accepts a keyboard or keypad input. I use it to accept 'touch tone' decoded digital outputs using my own phone line project that was published in *N&V* in 2010 to activate a monitoring program for my phone calls — even from cell phone use. Great project! Send in more useful projects like this.

John Mastromoro

(UN)Saturated

In the January 2014 article, "Build a PIC-Based Remote Temperature Sensor" there is a sidebar discussing saturation of a bipolar transistor. The definition in the sidebar is not correct. The correct definition of saturation is the state where an increase in base current does not cause an increase in collector current. The formula at the bottom of the sidebar yields this for the value of Rb: Rb = (Vin - VBEsat)/Ib. All this formula will yield is a value for Rb based on the desired Ib and Vin. It has nothing to do with saturation.

In order to calculate the minimum Ib required for saturation, you need to know the load voltage and the load resistance. This allows you to calculate the maximum current (ICmax = Vcc/Rload) that is

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PICAXE-Pi Communications — Part 1

At the end of the previous Primer installment, I posed three questions about the behavior of the *cylon10.py* program which we're going to address this month:

- **Why does one of the LEDs remain lit when you press ctrl-c to terminate the program?**
- **After terminating the program, why does the lit LED turn off when you type *GPIO.cleanup()* at IDLE's interactive prompt?**
- **Finally, why didn't we see something similar in our earlier experiments last time?**

We're also going to begin our exploration of PICAXE-Pi communications. However, before we tackle either of those topics, there are a couple of items that I want to discuss. So, let's get started!

Unzipping Archived Files on the Pi

If you have read earlier PICAXE-Pi articles here, you know that I have been posting the individual program files on my website because I hadn't been able to find a way to unzip the downloaded N&V zipped file. However, I recently received an email from a helpful reader (Margaret L.). The solution that she suggested is printed in the Reader Feedback section of last month's issue of *Nuts & Volts* — you may want to check it out.

Now that we're beginning our exploration of PICAXE-Pi communications, we're going to be working with both PICAXE BASIC programs and Python programs at the same time. As a result, we're going to need to download files to our PCs anyway, so I've decided to stop posting the individual program files on my website.

I think the simplest approach is to download the zipped file to a PC, unzip it, and transfer the Python programs to the Pi via a USB Flash drive, or by setting up the Pi as a server on the local network. (On the Pi, I also save all my Python programs directly on the Flash drive as a backup, in case my Pi crashes at some point.)

PICAXE Editor Beta is Now Available

The second topic that I want to mention is not in any way related to the Pi, but may be of interest to many Primer readers. Revolution Education recently announced the availability of a Beta version of the new Programming Editor software which has been renamed to "PICAXE Editor, version 6," or just PE6. RevEd emphasizes the fact that this is a Beta release so there may be minor bugs involved, and there will certainly be many changes before the final version of PE6 is released.

PE6 is a major re-write of the PICAXE IDE (Integrated Development Environment); it includes many powerful changes — some of which may be confusing at first. Conveniently, PE6 can be installed alongside version 5 of the Programming Editor, so we can easily experiment with it but still use our older (more familiar) software for our current projects.

When the final version of PE6 is released, we'll definitely discuss it in some detail. Until then, I just want to whet your appetite by mentioning one new feature that's been on my wish list for a long time: include files. This new capability in PE6 means that we will be able to simplify our PICAXE software in the same manner that we are now doing with our Python programs.

For example, we'll be able to write a PICAXE "module" that implements a fairly complex task (e.g., interfacing with an LCD display) and then simply write something like *#include LCD.basinc* in any program that requires an LCD display ("basinc" is the extension that needs to be used for any *include* file in PE6). If you're interested in experimenting with the Beta version of PE6, you can download it at **www.picaxe.com/Software/PICAXE/PICAXE-Editor-6/**.

On the same page, there's a link for downloading the "PE6 beta release notes" — a 24 page pdf file that describes the major features of the new software.

Now, let's turn our attention to the three questions from last time. The first two are relatively easy to answer. As you may remember, we used an infinite *while* loop to implement our scanning Cylon Eye. (If you need to refresh your memory, take another look at the *cylon10.py* program.)

Also, in the *blink(LED)* function that we used, we paused briefly to light each LED but we didn't pause at all after turning off each LED.

As a result — for all practical purposes — one of the LEDs is always lit whenever the program is running. Whenever we press ctrl-c, the program immediately exits which means that the *GPIO.cleanup()* statement isn't executed and one of the LEDs remains lit. Of course, when we manually execute the *GPIO.cleanup()* command at IDLE's interactive prompt, the GPIO pins are reset to their default input state, and the lit LED is turned off.

The third question (Why didn't we see something similar in our earlier experiments last time?) is a little trickier. In each of the earlier programs last time, we pressed a pushbutton to light an LED; when we released the button, the LED immediately turned off. So, unless you held the pushbutton down with a finger on one hand and at the same time pressed ctrl-c on the keyboard with two fingers on the other hand, the LED was never lit when the Keyboard Interrupt was executed.

As a result, it's easy to forget that the GPIO pins we were using in the program remain configured as outputs.

At this point, you're probably wondering why I'm spending so much time on what seems to be a trivial point. The reason is that I want to use our *cylon10.py* program to illustrate an important feature in Python. It's called "exception handling," and it's so important that most Python textbooks devote an entire chapter to it.

We certainly don't have enough space in the Primer to thoroughly discuss the techniques of exception handling, but I do want to cover the basics so that we can use this to our advantage in the Python programs we will be writing.

In Python, an exception refers to any set of circumstances that can result in a program being automatically terminated. Many exceptions are what we would call "errors." For example, if a Python program is in the process of writing a file to a disk and the disk becomes full, an error occurs and the program will automatically terminate (a.k.a., "crash").

On the other hand, our ctrl-c Keyboard Interrupt is also an exception; when the interrupt occurs, the program immediately terminates. However, the Keyboard Interrupt is definitely not an error; it's a Python feature that allows us to exit an infinite *while* loop.

In either case (an error or a feature), the point is that we want to be able to handle the exception gracefully. For example, we could allow the user to switch to another disk to save the file; or — in the case of the Keyboard Interrupt — we could terminate the program "gracefully" by executing a *GPIO.cleanup()* statement before exiting the program.

Handling Exceptions in Python

The two main statements that Python uses to handle exceptions are *try* and *except*. Let's examine a simple code snippet that uses those two statements to execute a *GPIO.cleanup()* statement before exiting our *cylon10.py* program when ctrl-c is pressed:

```
while 1:
  try:
    for LED in LEDs[0:9]:
      blink(LED)
    for LED in LEDs[9:0:-1]:
      blink(LED)
  except:
    GPIO.cleanup()
    print(“GPIO pins reset.”)
    print(“Program
terminated.”)
    break
```

The code in the *try* block above is the same as it was in our original infinite *while* loop. As long as we don't press ctrl-c, that's the only code that gets executed. In other words, the infinite *while* loop executes exactly as it did last time. However, as soon as we press ctrl-c, an exception occurs and the code in the *except* block is executed.

As a result, the GPIO pins are reset, we tell the user what happened, and the *break* statement is executed. I don't think we've used a *break* statement before, but its function is simple: It "breaks out" of the infinite *while* loop. Since there is no other code in our program, it terminates.

Because an exception occurred, you might think that the *break* statement isn't necessary, but it is. When we include *try* and *except* blocks in a program, Python no longer automatically exits the program when an exception occurs; it "assumes" we will handle the exception, including exiting the program if that's what we want to do.

As a result, if we accidentally omit the *break* statement, we create another error! The program does not exit, and the *while* loop executes again. However, we just reset the GPIO pins, so when Python tries to blink another LED, the program automatically exits with an error message stating that the LED has not been defined as an output!

Finally, there's a potential problem with the way I wrote the above code snippet. The *except* block will be executed whenever any exception occurs — not just the Keyboard Interrupt exception. Python includes dozens of different types of built-in exceptions, and many external modules include additional exceptions, as well.

In addition, we can even write our own exceptions if we want to. If any one of those exceptions occurs, the program will terminate unexpectedly, providing no clue as to what happened. The solution to this problem is to write the *except* statement so that it only applies to the exception that we want to "catch." (In Python jargon, the *except* statement "catches" the exception.)

In the above snippet, if we replace *except:* with *except KeyboardInterrupt:* we will only catch the interrupt; all other possible exceptions will cause the program to terminate normally with a (hopefully) helpful error message.

Post comments on this article and find any associated files and/or downloads at **www.nutsvolts.com/index.php?/magazine/article/february2014_PICAXEPrimer.**

Before reading further, you may want to experiment with adding *try* and *except* blocks to the *cylon10.py* program until you feel comfortable with the technique. When you're ready, we'll turn our attention to serial communications where we will encounter additional uses for *try* and *except* blocks.

Communication Options With the Raspberry Pi

The Pi's internal hardware implements three major communication protocols: I^{2}C, SPI, and serial. The question is: Which of these protocols do we want to use to communicate with our PICAXE processors? The answer, of course, is it depends!

Primarily, it depends on which PICAXE processor we're using in any given project. For example, if a fairly complex project requires the advanced capabilities of the PICAXE-20X2 processor, the I^{2}C protocol is the obvious choice for implementing PICAXE-Pi communication. The reason is when using I^{2}C communications, the Pi must be the master processor, and the X1 and X2 processors are the only PICAXE chips that can be configured as an I^{2}C slave. Therefore, I^{2}C communication with a Pi is not an option with PICAXE M2-class processors.

In my experience, however, the majority of PICAXE projects do not require the power (or expense) of a 20X2 processor. As a result, our Primer articles are going to focus on communication strategies that can be implemented with any PICAXE processor (M2, X2, or X1). If you're interested in I^{2}C communications between the Pi and a PICAXE X2- or X1-class processor, you may want to take a look at **www.instructables.com/id/PICAXE-Raspberry-Pi-ADC/**.

When using its built-in hardware for SPI communications, the Pi is also limited to functioning as a master processor; again, only the PICAXE X2- and X1-class processors are capable of implementing hardware-based SPI communications.

In addition, those PICAXE processors are also limited to master mode only for hardware-based SPI communications. (See the PICAXE documentation for *hspisetup, hspiin,* and *hspiout* in Section 2 of the manual.)

PICAXE BASIC also includes the *shiftin* (a.k.a., *spiin*) and *shiftout* (a.k.a., *spiout*) commands which implement software "bit-bang" versions of the hardware SPI commands mentioned above, but the software-based commands are also limited to the X2- and X1-class processors.

However, on M2-class processors, it's also possible to write our own bit-bang code to implement SPI functions. The documentation for the PICAXE *shiftin* and *shiftout* commands include sample code for implementing a SPI interface on any M2 processor, but the sample code also configures the PICAXE as the master processor so we still can't use that code to communicate with the Pi because it *also* insists on being the master processor!

One possible solution to this dilemma would be to write our own bit-bang routines that configure an M2-class processor as an SPI slave so we could communicate with the Pi as the master processor. I do intend to try that approach in the future, but for our first experiments I think that a serial communications link between the PICAXE and Pi will be easier to establish, so let's get started!

Configuring the Pi Serial Port

By default, the Pi's serial port is configured so that it can be used for debugging purposes. In other words, when you first boot the Pi, the long list of output that you see on the monitor is transmitted via the serial port. Since we want to configure the serial port so that we can use GPIO pins 14 and 15 to communicate with our PICAXE projects, the first thing we need to do is to disable the serial login connection. In order to do so, there are two files on the Pi that we need to edit: */etc/inittab* and */boot/cmdline.txt* — we'll use the *nano* editor for this purpose.

To edit the first file, open the terminal and type the following:

```
sudo nano /etc/inittab
```

Press return and move to the end of the file. You should see something similar to:

```
T0:23:respawn:/sbin/getty -L
ttyAMA0 115200 vt100
```

Comment out that line by adding a "#" character in front of it; then save the edited file.

To edit the second file, type this in the terminal:

```
sudo nano /boot/cmdline.txt
```

Press return — the file will contain the following (all on one line):

```
dwc_otg.lpm_enable=0
console=ttyAMA0,115200
kgdboc=ttyAMA0,115200
console=tty1
root=/dev/mmcblk0p2
rootfstype=ext4
elevator=deadline
rootwait
```

Edit the file by removing both references to the serial port (*ttyAMA0*). When you have finished, the file should contain the following (all on one line):

```
dwc_otg.lpm_enable=0
console=tty1
root=/dev/mmcblk0p2
rootfstype=ext4
elevator=deadline
rootwait
```

Save the edited file, and reboot the Pi by typing this in the terminal (and then pressing return):

```
sudo nano shutdown -r now
```

When your Pi has finished rebooting, the serial port (ttyAMA0) will now be available on GPIO pins 14 (TxD) and 15 (RxD), but we still need to install the *pySerial* package before we can begin exploring serial communication between the PICAXE and Pi. Before installing any new packages on the Pi, it's a good idea to first execute these two commands in the terminal:

```
sudo apt-get update
sudo apt-get upgrade
```

The upgrade process may take quite a while to complete. When it's finished, you need to execute one of the following commands in the terminal:

For Python3: `sudo apt-get install python3-serial`

For Python2: `sudo apt-get install python-serial`

At this point, we're finally ready to begin our exploration of PICAXE-Pi serial communication.

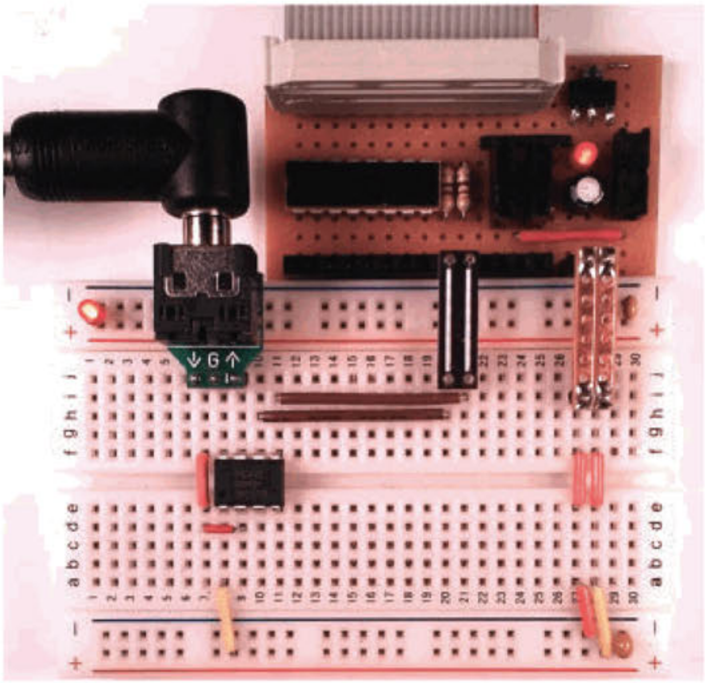


FIGURE 1. Breadboard setup for Experiments 1 and 2.

Experiment 1: Serial Output from PICAXE to Pi

In our first experiment, the Pi will receive serial data from a PICAXE-08M2 processor. (Actually, you can use any X2-, X1-, or M2-class processor — I just wanted to be sure the 08M2 is able to do the job.) The hardware setup is simple: Pin C.2 of the 08M2 is connected to GPIO 14 (TxD) on the Pi, and pin C.1 of the 08M2 is connected to GPIO 15 (RxD) on the Pi. My hardware setup is shown in **Figure 1**.

As you can see, I'm using the stripboard interface circuit that we constructed in an earlier Primer. However, you can use any hardware setup you prefer — just make sure that the 08M2 is powered at 3.3V to match the levels on the Pi's GPIO pins, and that there is a series resistor in the two I/O connections that we are using. (The stripboard interface circuit includes 470 Ω resistors on each GPIO line.)

Of course, we need two programs for this experiment: one for the Pi and one for the 08M2. As usual, go to the article link and download the zipped file that contains all the necessary programs for this month's Primer.

One approach is to unzip the file directly on your Pi if you have been able to get that working. If not, you can download the file to your PC, unzip it there, and transfer the Python files to your Pi either by using a USB thumb drive or by setting up the Pi as a server on your network. One way or another, you need to have the Python files on the Pi, and the PICAXE BASIC files on your PC.

For this experiment, the 08M2 program is *seroutToPi.bas* and the Pi program is *serinFromAx.py*. Let's start with the 08M2 program which simply sends the ASCII values for characters A through Z to the Pi in an infinite *do/* loop. The serial transmission is "True" (i.e., the line idles high) because that's the format required by the Pi. We don't need to discuss the details of the *seroutToPi.bas* program; when you read through the listing, you will see how simple it is.

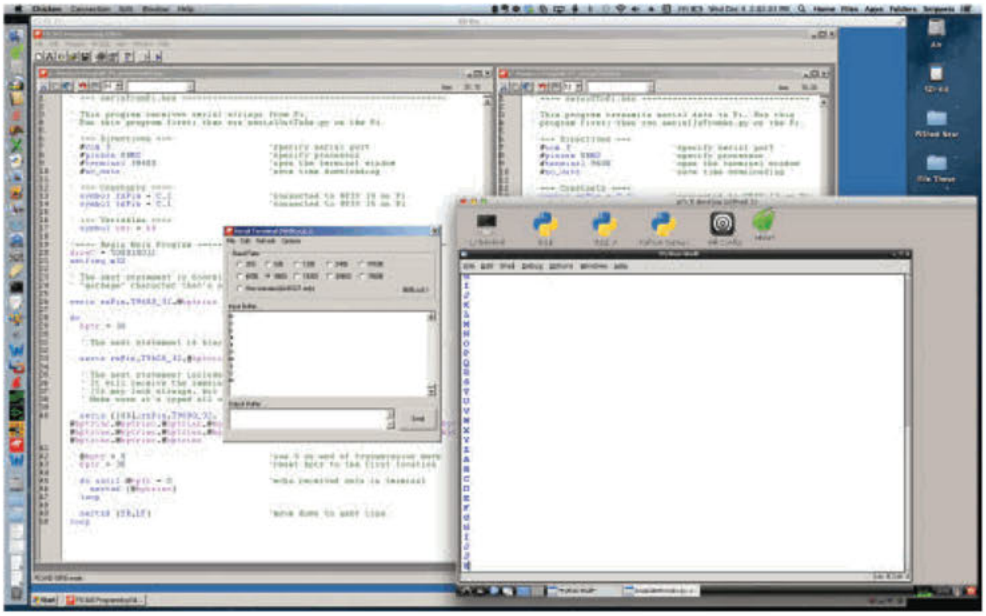
The Pi program (*serinFromAx.py*) is even shorter than the 08M2 program, but we do need to discuss a few details. In order to facilitate our discussion, the complete program follows:

```
A) # serialInFromAx.py
     (for Python3)
B) import serial
C) # define & open
  serial port
       @ 9600 baud
D) ser = serial.Serial
    (‘/dev/ttyAMA0’,9600)
E) while True:
F)    try:
G)       print(ser.read())
H)    except KeyboardInterrupt:
I)       print(‘Program
         terminated.’)
J)       ser.close()
K)       break
```

In the above code, the letters along the left edge are not part of the program; they are just there to facilitate our discussion. The following comments refer to the corresponding program lines above:

A) As the comment in this line indicates, the program is written for Python3 which makes it a little more complicated than it would be if it were written for Python2. We will discuss the main differences shortly.

B) This statement imports the *pySerial* package that we installed earlier. If you want to read more about this package, just search for "pySerial documentation" (without



■ FIGURE 2. Screenshot of output for Experiment 1.

the quotes). Also, note that we did not import *RPI.GPIO*; all we need is the *pySerial* package.

D) This is one way of declaring and opening a serial port in the *pySerial* package. Any name can be assigned to the port; I chose to use *ser* for brevity. In Python, all I/O devices (including serial ports) are treated the same as files, so the */dev/ttyAMA0* parameter indicates that the port we are opening (ttyAMA) is located in the *dev* folder, which is where all device files are located in Linux. The second parameter (9600) indicates that we're opening the serial port at 9600 baud.

Two additional points are worth mentioning:

- Whenever a serial port is defined, it's also automatically opened; a separate statement isn't needed to do that.
- All serial communication in Python is "True" (i.e., the line idles high), and it defaults to eight data bits, no parity, and one stop bit. These defaults work fine for communications with PICAXE processors, but if you're interested in changing any of them refer to the *pySerial* documentation.

F) The basic structure of the *try* and *except* blocks follows the same pattern we discussed earlier.

G) The *read()* function in the *pySerial* package reads a single byte. Also, by default, the *read()* function has no timeout. In other words, it's a blocking function — the program will wait at this point until a byte is received. This behavior can be modified by declaring a specific timeout when we initially configure and open the serial port. At some point, we will probably need to do that.

J) In the *except* block, we need to close the serial port before terminating the program. Leaving a serial port open when we terminate a program can cause problems for another program that attempts to open the same port.

When you've completed your hardware setup for this experiment (**Figure 1**), run the 08M2 program first and then run the Pi program. **Figure 2** is a screenshot of both programs running on my Mac. I'm using SSH to connect to my Pi, so the contents of its GUI appear on my Mac's desktop. If you have a monitor and keyboard attached to your Pi, you should see essentially the same results on two different monitors.

As you can see, the Pi's output is a little strange. For example, instead of displaying A, 'A', or 65, the Pi displays b'A'! That's Python3's way of saying that it's displaying a byte, which is one of several data types supported in Python3.

It took me a while to figure out how to convert the output to something more "normal." If you want to display the received bytes as their ASCII values, try replacing line G in the program with *print(ord(ser.read()))* and run the Pi program again. (You can just leave the 08M2 program running as you experiment with this.) You should see the appropriate sequence of numbers (65 through 90) on the screen.

On the other hand, if you would prefer to see the actual ASCII characters on your screen, replace line G with *print(chr(ord(ser.read())))* and run the program again. There may well be a way to accomplish the same thing with fewer parentheses, but I haven't found it yet. If you find one, please let me know!

Experiment 2: Serial Output from Pi to PICAXE

For our second experiment, we're going to reverse the direction of the serial link. This time, the Pi will send serial strings to the 08M2 processor using the same hardware setup we did in Experiment 1 (again refer to **Figure 1**).

As you probably know, PICAXE processors are not able to receive serial strings directly; it's necessary to store each received byte of the string in a separate variable. As a result, the PICAXE file for this experiment (*serinFromPi.bas*) is more complicated than the Pi's Python file. However, we aren't going to discuss it in detail because it's almost identical to the approach we took back in the

October 2011 Primer. (See the discussion of the *SerrxdFast14M2.bas* program in that article.)

Before we move on to discussing the Pi's Python program for this experiment, I do want to point out a couple of differences between the 2011 PICAXE program and the one that we're using in this experiment.

First, back in 2011 there was a bug in the PICAXE compiler that has since been resolved, so we no longer need to include the work-around that we used back then. Also, in the earlier article, we were using the *serrxd* command; this time, we're using the *serin* command but the technique involved is essentially the same. In addition, back then we used a 14M2 processor, and this time we're using an 08M2 processor. As I mentioned earlier, any current PICAXE processor can be used for our Pi experiments, so that difference isn't significant either.

When you have downloaded the *serinFromPi.bas* program, read through it to make sure you understand how it functions. If anything isn't clear, you may want to re-read the 2011 article I just mentioned.

When you're ready, let's move on to the discussion of the Pi program for this experiment (*serialOutToAx.py*). In order to facilitate our discussion, the complete program follows:

```
# serialOutToAx.py (for
Python3)

import serial
from time import sleep

# define & open serial port @
9600 baud
ser = serial.Serial
('/dev/ttyAMA0',9600)

# Allow 08M2 time to discard
garbage chr
sleep(.1)

while True:
  try:
    ser.write(b'Hello
    PICAXE')
    sleep(1)
    ser.write(b'I said Hi!')
    sleep(1)
    ser.write(b'Where are
    you?')
    sleep(2)
  except KeyboardInterrupt:
    ser.write(b'Keyboard
    Interrupt')
    ser.close()
    break
```

There are two points in the above program that I want to clarify. First, in previous programs, we have written *import time* which imports all the functions included in the time library. The alternate version that we're using in this program has two advantages: only the sleep function is imported (which is all we currently need), so this version of the *import* command reduces the size of our program; and we can use a *sleep()* statement without needing to write *time.sleep()*.

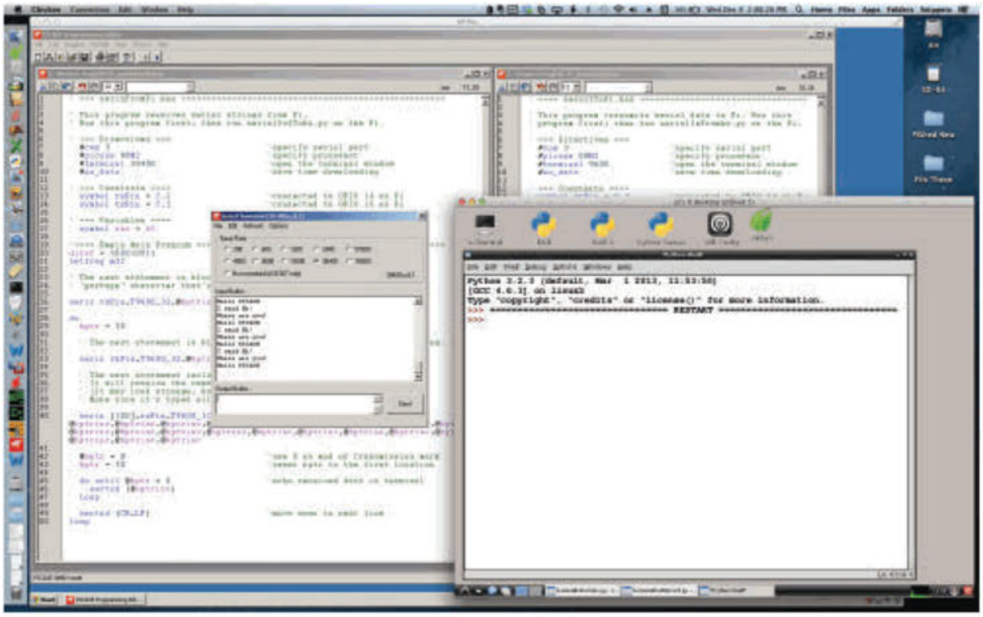
In this program, we're sending three different strings to the 08M2. In Python2, that was a simple matter (e.g., *ser.write('Hello PICAXE')*. However, in Python3 there's a complication similar to what we discussed in our first experiment. We need to send the string as a series of bytes. Including a lowercase *b* in front of each string accomplishes that goal.

There are more complicated ways of doing the same thing, but the above approach seems to work well. **Figure 3** is a screenshot of both programs running on my Mac; your results should be similar.

Once again, we're out of space this month! Next time, we'll continue our serial communication experiments and use an 08M2 processor to help the Pi accomplish something that it can't do on its own. As you know, the Pi doesn't have any analog inputs but PICAXE processors have plenty of them (three on the 08M2, seven on the 14M2, and 11 on the 20M2).

As a demonstration of how PICAXE can help the Pi, we'll interface an MCP9700A analog temperature sensor with an 08M2 processor and serially send the temperature reading on to the Pi for display. As you may remember, we have already accomplished the PICAXE portion of this task (the December 2012 Primer), so you may want to re-read that article to get a jump on things. In fact, you might even try to implement your own working system before the next installment.

Whatever you do, have fun! **NV**



```
Hello PICAXE
I said Hi!
Where are you?
Hello PICAXE
I said Hi!
Where are you?
Hello PICAXE
I said Hi!
Where are you?
Hello PICAXE
```

```
Python 3.2.3 (default, Mar  1 2013, 11:53:50)
[GCC 4.6.3] on linux2
Type "copyright", "credits" or "license()" for more information.
>>> ================================ RESTART ================================
>>>
```

■ FIGURE 3. Screenshot of output for Experiment 2.

In this column, Russ answers questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions. **Send all questions and comments to: Q&A@nutsvolts.com**

- **Trickle Charger**
- **Ham Mobile Radio Setup**
- **Electronic Player Piano**

Post comments on this article and find any associated files and/or downloads at **www.nutsvolts.com/index.php?/magazine/article/february2014_QA.**

Trickle Charger

Q Could you provide a circuit to make a 12 VDC trickle charger for my home generator? The battery is gel type. I want to build it using a 12.5 VAC x 4.5 amp transformer. Thank you for your past help.

— Ken Bartone

A A 12 amp-hr battery should tolerate a constant trickle current of 100 mA, but battery manufacturers recommend float charge for long term storage. The difference is that a float charger limits the voltage to 13.8 volts for lead-acid batteries of six cells.

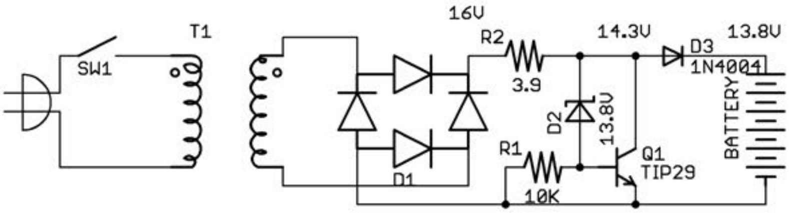
A bridge rectifier will give a peak voltage of about 17.5 volts; with a full wave bridge rectifier, the DC voltage will be about 16 volts peak. Referring to **Figure 1**, if the battery is to be float charged at 13.8 volts, the voltage at the Q1 collector will be 14.3V which means the zener (D2) must be 13.8V. R1 shunts any zener leakage to ground to prevent Q1 from turning on prematurely. R2 limits the peak current to less than one amp: (16-14.3)/4 = 0.425 amp and the average current — according to my handbook — will be 0.135 amps.

When the battery is fully charged, all the current flows through Q1 and its power dissipation is: 14.3*.135 = 1.9 watts. Q1 is rated at two watts with no heatsink, but for reliability I would use a heatsink of 30 deg C/watt at least.

The power in R2 is: I^2*R = 0.07 watts, so a 1/4 watt resistor will be fine. A bridge rectifier rated at one amp is available in a four-pin DIP package to complete the design.

D3 is necessary to protect Q1 in case the generator charging circuit tries to charge the battery to more than 13.8 volts.

■ FIGURE 1.



PARTS LIST MOUSER PART NUMBERS

PART	DESCRIPTION	PACKAGE	PART NUMBER	COST $
D1	ONE AMP BRIDGE	4 PIN DIP	583-DB101	0.38
R1	10K, 5%, 1/4 WATT	RC07	291-10K-RC	0.10
R2	3.9 OHMS, 5%, 1/4W	RC07	291-3.9-RC	0.10
D2	ZENER,13.8V,2%,1/2W	SC-40	771-NZX14B,133	0.19
Q1	NPN, 50V, 1AMP, 2W	TO-220	512-TIP29A	0.57
D3	400V, 1AMP	DO-41	625-1N4004E-E3/73	0.08
HEAT SINK	19 DEG C/W		532-7136DG	1.02

Ham Mobile Radio Setup

Q I had to move and disconnect all my radios and antennas from my car. I am now in the process of rebuilding the VHF and HF power system. I want to make sure that when the car is shut off, the radios will shut off within 10 minutes to save my car battery. Do you know of a schematic that will do the job?

— Jim Houser WA8JIM

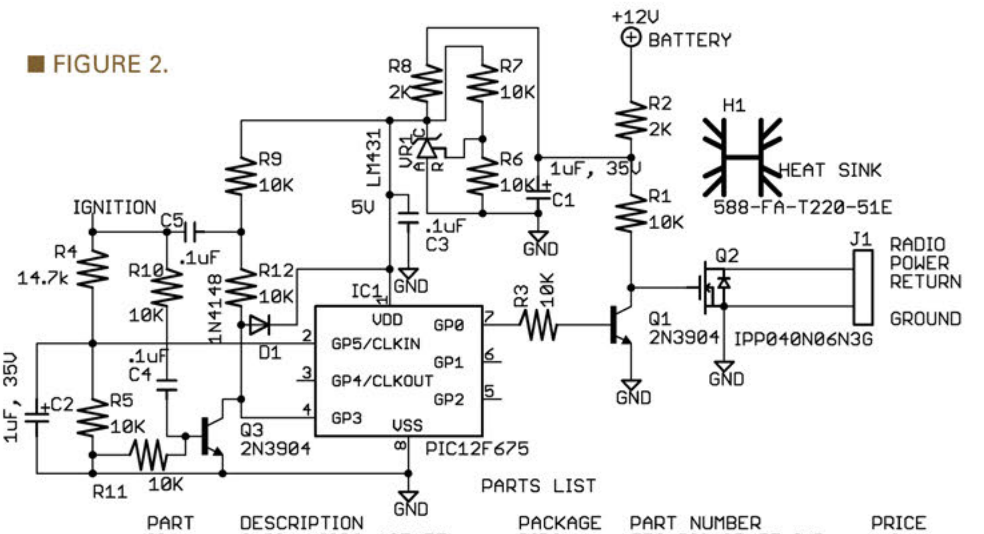
A I know the problem, but 10 minutes is a long time for a 555 timer. A PIC12F675 will do the job with fewer parts. In **Figure 2**, the 12 volts from the ignition switch going down starts the time. Five volts for the PIC will be supplied by a programmable zener diode because its current requirement is low. I don't know the current drain of the radios, but 30 amps should be adequate.

What is needed is a 30 amp 60 volt switch that can be controlled with a five volt signal. That in itself is pretty simple, but the design is complicated by the need to protect the circuit from the 60+ transient volts that are expected in an automotive system.

In **Figure 2**, the components R2, C1, R4, C2, R10, R12, and D1 are for transient protection. D1 is necessary because pin 4 does not have a diode to VDD; only one to VSS. R4 and R5 provide a safe +5V to pin 2 (GPIO.5) when the ignition is on.

When the ignition is turned off, IC1 is reset immediately through C5 and R12, and the program starts looking for a low in pin 2 — which happens after a short delay caused by C2. Then, the 10 minute delay starts, at the end of which pin 7 (GPIO.0) goes high permanently turning Q2 off. When the ignition is turned on, IC1 is reset through R10, C4, and Q3 which starts the program running again, looking for the ignition to be turned off. **Figure 3** shows the power-off delay program. A file is available at the article link. (If you want to build this, I can supply a programmed PIC12F675 for $5.)

■ FIGURE 2.



PARTS LIST

PART	DESCRIPTION	PACKAGE	PART NUMBER	PRICE
IC1	8 PIN MICRO 12F675	DIP8	579-PIC12F675-I/P	1.21
VR1	PROG. SHUNT REGULATOR	TO-92	512-LM431ACZX	0.41
Q1, Q3	GP NPN 2N3904	TO-92	512-2N3904TAR	0.17
Q2	N-MOS, 60V, 90A, 4mOHM	TO-220	726-IPP040N06N3G	2.67
HEAT SINK , 3.5 DEG C/W			588-FA-T220-51E	1.96
C1, C2	1uF, 35V, TANTALUM		80-T353A105J35AT-TR	1.34
C3, C4, C5	0.1uF, 10%, 50V, CERAMIC		581-SR215C104JARTR2	0.33
D1	ANY SIGNAL DIODE	DO-35	583-1N4148-B	0.03

```
'*****************************************************************
'*  Name      : POWER OFF DELAY.BAS                              *
'*  Author    : RUSSELL KINCAID                                  *

'*  Date      : 11/20/2013                                       *
'*  Version   : 1.0                                              *
'*  Notes     : TURN OFF OF IGNITION POWER STARTS DELAY          *
'*            : TURN ON OF IGNITION ENABLES TIMER                *
'*            : DRAIN ON BATTERY IS ABOUT 2 mA                   *
'*****************************************************************

 REM DEVICE = 12F675

CMCON = 7                   'SETS DIGITAL MODE
ANSEL = 0                   'GPIO.0 TO GPIO.3 SET AS DIGITAL
TRISIO = 40         'LINE 18 GPIO.5 IS INPUT, ALL OTHERS OUTPUT EXCEPT
                            'GPIO.3 WHICH IS MASTER CLEAR.
GPIO = 0                    'ALL OUTPUTS SET LOW   LINE 17
OPTION_REG = %11010000      'INTERNAL PULLUPS DISABLED
N VAR BYTE
DEFINE OSCAL_1_1K 1          'TO SAVE OSCILLATOR CALIBRATION


    PAUSE 2000              'PAUSE 2 SEC TO ALLOW VOLTAGES TO STABELIZE
 START:
    IF GPIO.5 = 0 THEN GO
    GOTO START

GO:                         'LINE 27
    FOR N=1 TO 10
    PAUSE 60000            'WAIT 60 SECONDS
    NEXT N
    HIGH GPIO.0             'TURN OFF RADIO POWER
    REM RADIO POWER IS PERMANENTLY OFF UNTIL IGNITION IS TURNED ON
    REM WHICH CAUSES A RESET TO ENABLE THE TIMER AGAIN.
    END
```

■ FIGURE 3.

Electronic Player Piano

Q I have an old player piano mechanism that I want to convert to electronic. When a note is to be played, a hole in a paper roll passes over the corresponding "hole" in a metal bar. I have thought about light detectors or even pressure detectors to detect the paper hole but I need something simple, small, and reasonably cheap. I was also thinking about using either a hacked electronic keyboard or a microprocessor to generate the music. Any ideas to get me going?

— Phil Fitzjarrell

A I have a player piano, so I know something about how it works. Your project is very interesting to me. One solution is a small rotating wheel (88 of them) that falls through the hole in the paper and completes a circuit. This is electrically simple but mechanically complex. Not being mechanically inclined, I will opt for a photosensor solution. The piano paper roll is normally white but some of mine have yellowed with age. The paper is slightly more than 11 inches wide and has up to 88 slots (.050 inches wide) which correspond to the 88 keys, plus another slot which I think is for automatic pedal operation. I measured the holes in the metal bar (see **Figure 4**) which turned out to be .075

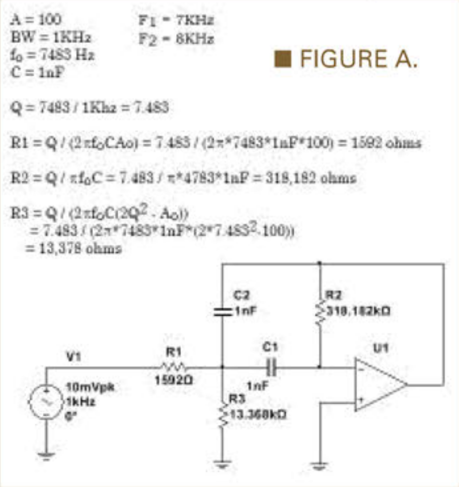
MAILBAG

Re: Bandpass Filter, page 20, December 2013:

#1 I was looking over your calculations for the filter in the December issue, and it struck me that there was a resistor missing from the design we use in class. If you add R3, the calculations go as indicated in **Figure A**. I ran the bode plotter in Multisim, and got results very close to your design goals. I haven't built the circuit in the lab yet, but maybe soon. I really enjoy reading your solutions and explanations. Please keep up the good work.

Ron Tinckham, Professor
Biomedical Engineering Technology
Santa Fe College

*Thanks for your interest; this circuit (**Figure A**) is the one I usually use for an RC bandpass. I was intrigued by the circuit sent by Bob Wojcik because I had not seen it before. The calculations got so complicated that I made C1 = C2 to simplify, but forgot there were now only two variables. So, gain, frequency, and bandwidth could not all be specified. That is why my results were off. I leave the calculations to interested parties!*


■ FIGURE A.

A = 100
BW = 1KHz
f_0 = 7483 Hz
C = 1nF

F1 = 7KHz
F2 = 8KHz

Q = 7483 / 1Khz = 7.483

R1 = Q / ($2\pi f_0 CAo$) = 7.483 / (2π*7483*1nF*100) = 1592 ohms

R2 = Q / $\pi f_0 C$ = 7.483 / π*4783*1nF = 318,182 ohms

R3 = Q / ($2\pi f_0 C(2Q^2 - A_0)$)
= 7.483 / (2π*7483*1nF*(2*7.483^2-100))
= 13,378 ohms

#2 I enjoyed working through your equations regarding the bandpass filter problem. The circuit is called an Infinite-Gain Multiple Feedback Bandpass Filter; **Figure A** is actually taken from *Rapid Practical Designs of Active Filters*, D. Johnson & J. Hilburn, Wiley 1975, page 139. The equations from the book are:

Gain = -R2/R1/2
B = 2/R2/C
$\omega_0^2 = (1/R3/C^2)(1/R1 + 1/R3)$

Referring to **Figure A**, B is the bandwidth about the center frequency F0, being equal to F2 – F1.

Q = ω_0/B and C = C1 = C2. R3 is missing from the problem circuit, so the term 1/R3 disappears from the equation for ω_0^2.

Using your numbers:
R1 = 1,589 ohms
R2 = 317,844 ohms
C = 10^{-9} farads.
Then
G = 100.01 (40 dB voltage gain)
B = 1.001 kHz
ω_0 = 44,500 radians/second = 7.082 kHz
Q = ω_0/B = 7.07

Peter A. Goodwin

Thanks for the feedback. The equations that you supplied made me realize that by making C1 = C2, I had lost control of one of the variables and that is why my results were not as expected. It is necessary to keep the ratio C1/C2, but that is too complicated to bother with. The three-resistor circuit is tunable via R3 without affecting gain or bandwidth. The two-resistor circuit is not tunable.

Re: More on the Jacob's Ladder, page 20, November 2013:

Looking at the article on Jacob's ladder; I'm confused on coils/HV being directly connected to the Q1 drain. Shouldn't it go to output? I want to use this as a fence zapper, but it looks like max smoke to me. So, does the July issue seem right?

Fred

Figure 1 in the November issue was intended to be like the figures in the July issue; the HV at the top of the ignition coil near terminal 4 is where the arc forms. I want to caution you that if used as a fence controller, it could be lethal depending on the frequency. Fence controllers usually produce a pulse every second or so. If you reduce the frequency of the oscillator, it could be a real attention getter but not lethal. Ideally, the secondary should be isolated from the primary, but ignition coils are not built that way. The spark current coming back through ground could over-stress C3. To avoid that, connect Q1 drain to earth ground and operate the circuit from a battery.

Re: NiCad Battery Chargers, page 22, December 2013:

Just received the December 2013 issue of *Nuts & Volts*. Had to comment on Don's question on page 22, Figure 4. Don specified a battery charger rated 2.9/8.7 VDC at 105/12 mA with humming. No burnt resistors and LEDs light up. I redrew half of the circuit; the 24 ohm resistor is the current limiter.

The LED turns on with sufficient current across the 24 ohm resistor and the (120/260 or 120/350 ohm) resistor and diode divider network; 110 volts applied across the 24 ohm resistor at 50 percent duty cycle from D5 or D6 would require about 126 watts.

Battery connections are not shown. As drawn in the diagram, D1 through D4 are shorted by jumpers (brown, black, green, gold, and silver).

If silver is replaced by two cells in series or green is replaced by a 7.2 volt battery, numbers work out.

Source is 8.7 VAC for two-cell and one diode with a 24 ohm resistor gives (8.7-2.4-1)/24 = 220 mA => at 50% duty cycle = 110 mA.

The NiCad nine volt battery gives 7.2 volts.

(8.7-7.2-1)/24=20.8 => 20.8/2=10.4 mA which is close to the original specification.

The only element that could hum in this circuit is the transformer at the bottom of the diagram. D1 and D3 appear to be reverse-charge protection for cells.

My conclusion: The batteries were inserted in reverse and will not charge.

Edward Wade

Thanks, Ed, for your thoughtful analysis of the battery charger circuit.

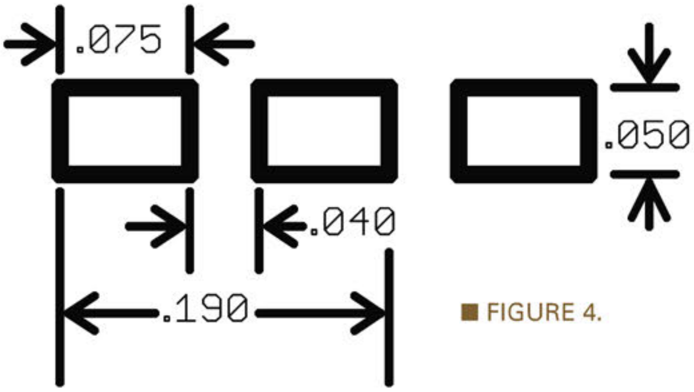
inches; I calculated the hole-to-hole spacing to be .075. That is plenty of room for an 0805 IR emitter and sensor.

Mouser has an emitter and sensor in one package that is .067 wide (part number 852-GP2S60B; 42 cents each per hundred). This is a reflective system; the IR bounces off the paper to a phototransistor. The optimum spacing is .020, so a sheet of .020 plastic that is transparent to IR will be optimum, and will protect the paper from the sensors. The phototransistor will be turned on when the paper is present and off when there is a hole. That is probably the opposite of what is wanted, but an inverter will solve that problem.

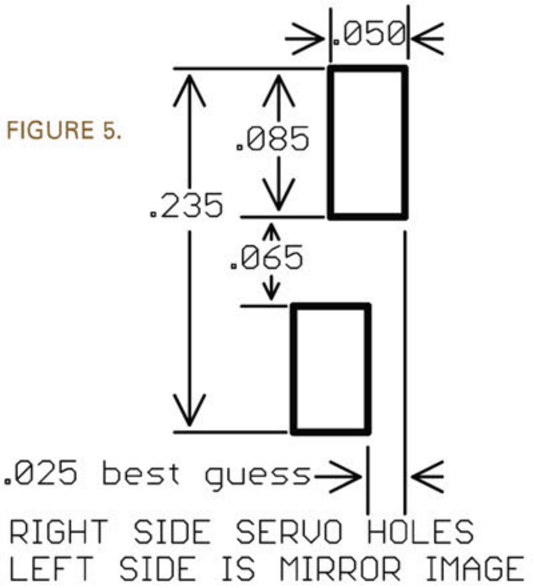
Another solution is an IR emitter on one side of the paper and a phototransistor on the other. Mouser has these in the 0805 package also (part number 638-PT1721BL41TR8 for the phototransistor and 638-IR1721CTR8 for the matching IR emitter). The paper is somewhat translucent, so some intensity adjustment may be needed. A variable speed stepper motor to turn the rolls would be the easiest, but an analog speed servo would also work.

The metal bar has holes at the edges of the paper to operate a servo that keeps the paper in the center; you will want to implement that. I would do an analog servo; I don't know how to do a digital servo. I suppose a bang-bang servo (where the paper is moved .025 or less) would work. If the left sensor is covered, the paper moves right until the right sensor is covered, then it moves back. I think the servo in my piano is two speed because there are two holes on each side of the paper, slightly offset (see **Figure 5**). I don't see the paper moving back and forth; it stays in the middle.

Your idea of hacking a keyboard is great; it opens up all kinds of innovative possibilities. **NV**



■ FIGURE 4.



■ FIGURE 5.

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EXTREME Joule Thief 3 Watt CREE LED
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AUTORANGING FAULT LOCATOR

EDS — maker of the CapAnalyzer 88A — announces the new LeakSeeker 89 Autoranging Fault Locator model EDS-89, which replaces the original LeakSeeker 82B short and leaky fault locator manufactured from 1995 to 2012.

The American-made LeakSeeker 89 locates the exact spot on a printed circuit board (to within a fraction of an inch) where a shorted or leaky component is bringing a power supply bus or data line to ground. It is able to locate defects from zero to 300 ohms with no loss of resolution. It can even find active shorts that a DVM won't show. The high GAIN mode can locate shorted components on multi-layer boards with ground planes and a power layer. Three fully automatic range settings allow easy finding of faults along thin, normal, or wide/ground plane copper PCB runs. A video at **www.youtube.com/watch?feature=player_embedded&v=BUyEe8G50D4** is available. A 60 day satisfaction or money-back guarantee is included. A copy of the operation manual is available

For more information, contact:
EDS
www.eds-inc.com

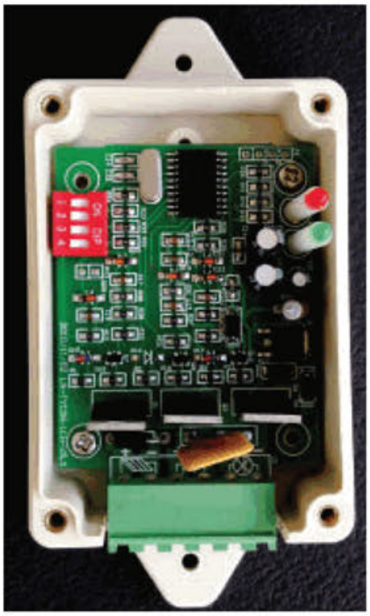
SOLAR PANEL CONTROLLER

The SCLED-12V5A-T Solar Panel Controller from J2 LED Lighting uses microcontroller circuitry with user selectable nighttime on functions for LED lighting. The dusk to dawn function works by sensing the voltage of the solar panel. The controller is in dawn mode when the ambient light load on the solar panel produces a voltage over 4.5 volts (ref.). In this mode, the controller's output is off.

The dusk mode is activated when the panel voltage drops to below 4.5 volts (ref.) due to a lack of ambient light. In this mode, the controller turns the output on to the LED lighting load. A switching delay reduces false triggering with fluctuations in cloud cover.

An internal user selectable DIP switch provides the option to limit the amount of time the light is on to two, four, six, or eight hours. The controller also provides standard dusk to dawn control with no time limiting. The time limiting function is useful for various applications in which battery size and/or panel size may need to be reduced by limiting operating time of the LED lighting load at night. The controller also functions to protect the battery (SLA, Sealed Lead Acid) from over-charge and under-charge.

The controller has internal voltage sensing that monitors the battery voltage. The controller will disconnect the LED output load if the battery voltage falls below 11.6



volts (ref.). The controller will allow operation again when the battery voltage recovers to 12.5 volts (ref.). The charge power to the battery is a PWM (Pulse Width Modulation).

An internal TVS (Transient Voltage Suppressor) protects the unit from voltage transients that may occur from nearby lightning strikes to the solar panel. An internal auto resetting polymer fuse on the battery connection provides protection from current and thermal overload.

The solar panel and LED lighting load connections of the controller are recommended to be fused at five amps maximum. Any additional fusing guidelines from the solar panel and battery manufacturer should be followed. A solar panel for a 12 volt system should be used. A 12 volt solar panel rated at 60 watts is the maximum size for the SCLED-12V5A-T controller. The largest size of battery recommended is 40 amp-hours. Smaller amp-hour batteries may be used if sized accordingly to the solar panel and load.

The SCLED12V5A-T is minimally "weather resistant" and needs to be mounted so as to be protected from direct exposure to water/moisture. To ensure an extended life of the controller, mount it in a semi-covered place out of the elements. A standard NEMA electrical enclosure rated for the operating environment may be used for protection of the controller.

Electrical characteristics include: Module rating is 60 watts max at 12 volts DC, five amps max. Max idle current in off state is 7.0 mA max.

Electrical specifications are as follows:

- Working Temperature: -20°C-60°C.
- Dimension: L72 x W38 x H28 mm.
- Rated voltage: 12V DC.
- Rated charging current: five amp max.
- Float charge/rapid charge: 13.6–14.6 volts DC (PWM).
- Over-discharge low voltage disconnect: 11.6 volts.
- Over-discharge recover voltage: 12.5 volts.
- Ambient Light Sense (ALS) dusk to dawn switching at 4.0–4.5 panel volts (ref. 10 Lux panel light), >10 seconds switching delay.
- Intended to control LED lighting loads only and for use with SLA battery only. Maximum recommended battery size is 40 amp-hours; maximum 12 volt solar panel size is 60 watts.
- Wiring polarity is defined by case marking; use no smaller than 18 AWG wire UL1007 or equivalent; fuse with no larger rating than five amps.

Pricing is as follows (in USD): 1-4 units $22.50 ea; 5-99 units $19.99 ea; and 100-250 units $16.99 ea

For more information, contact:
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CLASS D BLUETOOTH AMPLIFIER

Parts Express announces their new, highly capable Lepai audio product. The compact and efficient Lepai LP7498E stereo amplifier delivers a pristine 100 watts into eight ohms per channel, thanks to its Class D output circuit design.

Features include:

- Ample, clean Class D amp output for music and multimedia.
- Advanced STMicroelectronics TDA7498E audio amplifier chip.
- Wireless music streaming via Bluetooth connection.
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- Power supply included.

Because of its useful power-to-size ratio, this stereo amplifier is perfect for desktop systems, bookshelf speakers, and most home (or office) audio applications. The black chassis and laser engraved silver faceplate provide a modern cosmetic touch.

The LP7498E employs the highly efficient STMicroelectronics TDA7498E audio amplifier chip, which is capable of 160 + 160W output into four ohm loads, or 1 x 220 watts bridged mono. Internal components are sourced from brands such as NEC and Alps. Integrated thermal protection ensures long life and trouble-free operation.

High quality binding posts (5/8" on center) accept bare wire, 3/8" spade terminals, or standard banana plugs for problem-free speaker connections. RCA L/R inputs are incorporated for analog connection (cable not included). Each LP7498E is shipped with its own 36 VDC 4.5A power supply.

The LP7498E also enables Bluetooth connectivity to wirelessly stream audio from an iPhone, Android smartphone, tablet, or laptop. The Lepai LP7498E amplifier's low price and accurate neutral sound character make it an ideal partner for workbenches and test stations.

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UNIQUE MODULAR PROJECT SYSTEM

Take what you need, leave out what you don't! This is the slogan for the new Tibbo Project System (TPS) featuring Tibbit™ I/O modules available new from Tibbo Technology. Tibbits (as in "Tibbo Bits") are blocks of prepackaged I/O functionality housed in color-coded plastic shells. Want an ADC? There is a Tibbit for this. A 5V power supply? Got that. RS232/422/485 port? PoE? PWM? These, and many other Tibbits are available, as well.

Tibbits are divided into Tibbit modules and Tibbit connectors.

Each TPP (Tibbo Project PCB) can accommodate multiple Tibbit modules and connectors. Only bare essentials are provided on each board. There is a CPU, an Ethernet port, and a very simple power supply.

The rest of the board's functionality is defined by what Tibbits are plugged in. There are several TPP "sizes" that differ in the number of Tibbits they can accommodate.

As with most Tibbo products, TPPs are programmable in a language called Tibbo BASIC. This easy to learn programming language is particularly suited for control, automation, and networking applications. Tibbo BASIC is complemented by a rich set of programming objects. There are objects for socket (TCP, UDP, HTTP) and serial communications, Wi-Fi, GPRS, file data storage, LCD and keypad control, and many other functions.

Tibbo BASIC applications are created using the free Tibbo IDE (Integrated Development Environment) software (TIDE). This software features a built-in debugger allowing users to upload their Tibbo BASIC application onto the TPP board, and cross-debug it through the Ethernet LAN without the aid of any special debugging hardware (such as a JTAG board or an ICE machine).

More than just an enclosure for TPP and Tibbits, a Tibbo Project Box adds an aesthetic touch to automation projects.

The top and bottom walls of an assembled project box are formed by two rows of connector Tibbits installed on a TPP.

The front cover of the box is made of translucent plastic that allows users to see the status LEDs of Tibbit modules installed inside. The front panel also accommodates paper inserts similar to those found on office telephones.

The inserts are meant for marking wires and ports of a TPS-based automation device.

To aid users in the evaluation and creation of TPS-based automation products, Tibbo has designed an online configurator. Name the project, select the TPP board, place required Tibbits, and the configurator will notify builders of potential problems and even calculate the projected power consumption.

Pricing for barebone systems range from US$89-$106; Tibbits range from US$2-$100. All parts can be purchased separately. Check out the website for specific costs.

For more information, contact:
Tibbo Technology
http://tibbo.com

LOW POWER RADIO TRANSCEIVER

Saelig Company, Inc., has introduced the STD-502-R 2.4 GHz transceiver which uses direct sequence spread spectrum (DSSS) modulation and a true diversity circuit, enabling reliable communications even in the congested 2.4 GHz band.

The STD-502-R complies with the European ETSI EN300440, US FCC Part 15.247 standards and Japanese ARIB STD-T66 standard, making it ready for the global market.

Low power consumption and battery operation give the STD-502-R the performance demanded for in applications where long range and reliability are required.

The transceiver uses a transparent data interface to enable users to communicate using their own protocols, with 77 available channels at a line-of-site range of up to 300 m.

Designed to be embedded in equipment, the STD-502-R was

Continued from page 27

developed as a radio module for industrial applications that require reliable operation. Besides using highly noise-resistant DSSS modulation, the module has a true diversity receiver function for preventing signal dropout due to multi-path fading.

The modules can be easily set via the RS-232 UART interface using dedicated commands. Spread-spectrum correlation is done in a custom onboard ASIC instead of relying on conventional RFICs.

The STD-502-R module itself has no built-in communication protocol. Instead, it has a transparent RS-232 data input/output interface, enabling users to employ their own protocols without modification.

In addition, it can continuously transmit a low or high signal without restriction.

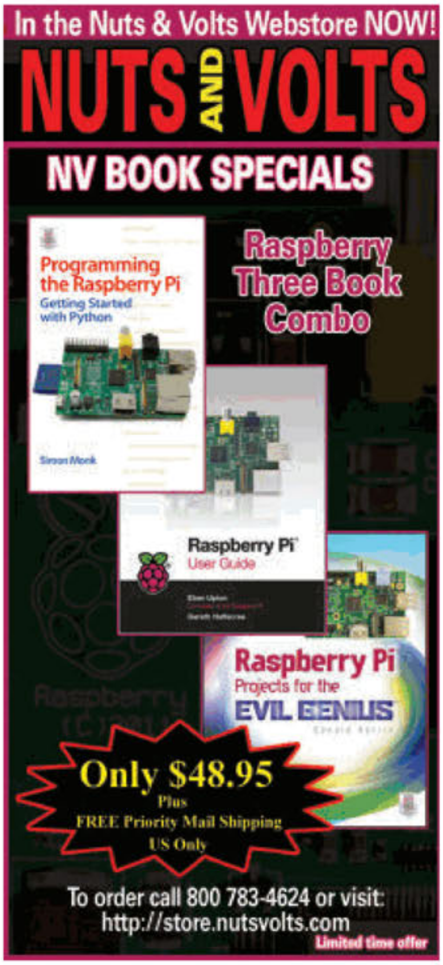
An evaluation board (the TB-STD502) allows testing of the STD-502-R module to perform range, data packet, and switching signal transmission tests.

Onboard LEDs, CH switch, ID switch, and pushbuttons can exercise switching signal tests and packet tests with packet error indication.

The STD-502-R is designed for an operating temperature range of -20 vto +65 °C with an RF power of 10 mW (3.3V 65 mA), and is intended for the remote control of industrial equipment or for industrial measurement systems.

Retail price is around US$105.

For more information, contact:
Saelig
www.saelig.com



Programming the Raspberry Pi
Getting Started with Python
Simon Monk
Raspberry Pi User Guide
Raspberry Pi Projects for the EVIL GENIUS

IMPROVED EFFICIENCY 13.8V POWER SUPPLY

By Robert Atkinson

Post comments on this article and find any associated files and/or downloads at **www.nutsvolts.com/index.php?/magazine/article/february2014_Atkinson.**

Many radio enthusiasts and other hobbyists use or repair equipment intended for automotive use. This requires a source of power, nominally 13.8V DC. Many designs have been published using the ubiquitous 2N3055 as the linear pass element. These can be inefficient. More recent are switching regulator designs. Unfortunately while efficient, these can generate unacceptable levels of electrical noise. Here is a linear design modernized with MOSFET pass elements that improve efficiency with no switching noise.

The Problem

With older bipolar (BJT) designs, you have the low current gain and large voltage drop of the pass transistor (read the **sidebar** Overhead in Bipolar). This requires higher unregulated voltage and consequently a larger transformer and heatsink.

In contrast to the BJT, Metal Oxide Semiconductor Field Effect Transistors (MOSFETs) require no steady state drive current and have a low "on" resistance. The downside is that they require about seven volts on the gate to pass high currents. As this is with respect to the output voltage, the gate will be at around 21V. Using the high current unregulated supply to provide this would be worse than the BJT design. An additional transformer and rectifier could be used, but adds to the cost.

This design uses a voltage doubler to provide the supply for the regulator and gate drive. It's rated at 14A continuous or 20A peak duty but can be scaled up or down as required. It's equivalent to a commercial "20 amp" supply costing around $100.

Circuit Description

Refer to **Figure 1**. The incoming mains is fused and switched before being applied to the primary of T1 — a 300VA toroidal transformer with two 15V secondaries connected in parallel. The AC is full-wave rectified by bridge rectifier BR1. The rectified output is smoothed by C1 and C2, which are 10,000 µF electrolytics. The voltage at this point is approximately 19V under load.

The higher voltage required by the regulator is provided by a voltage doubler comprising C3, D2, D3, and C4. This does not look like a voltage doubler unless the main rectifier and filter capacitor are considered. Note that one side of C3 is connected to the AC output of the transformer. On the negative cycle of the AC, C3 charges to the peak of the AC via D1 and the upper right-hand diode of BR1.

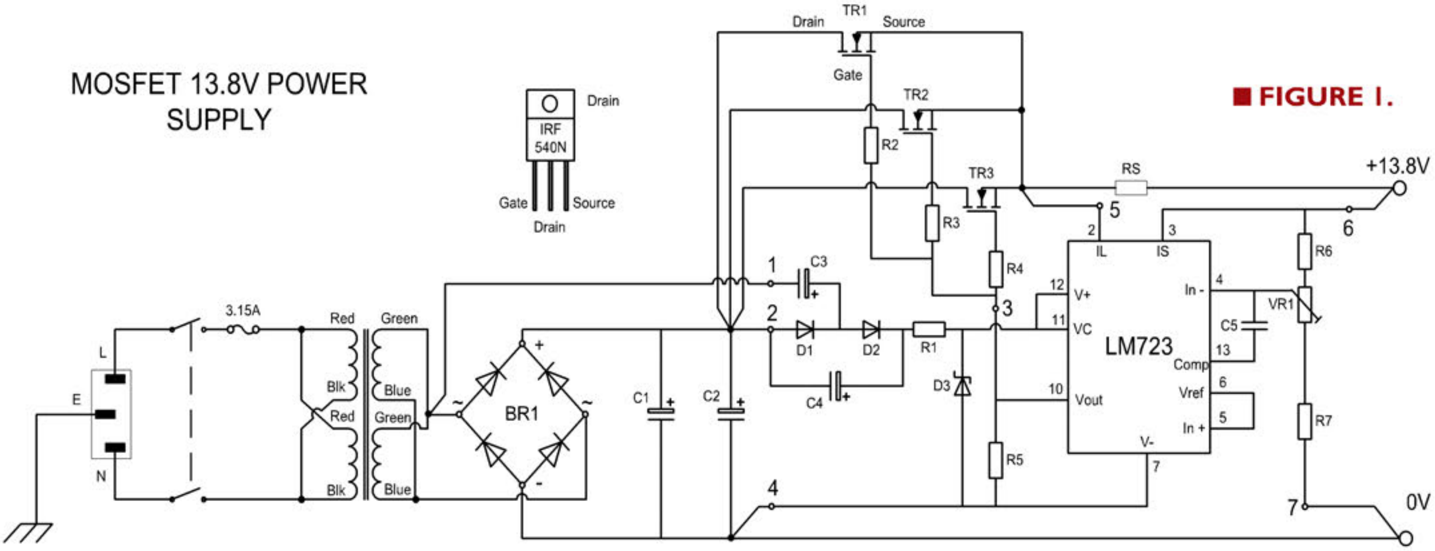
On the positive half cycle, the charge on C3 is transferred to C4 via D2. As C1/2 and C4 are each charged to around 20V and are in series, the voltage at the junction of D2 and C4 is 40V. As this exceeds the LM723 rating, a simple shunt regulator — R1 and zener diode D4 — provides 36V to LM723. This also improves the line regulation.

The LM723 is an older IC that is simple to use and low cost. Internally, it has a voltage reference (7.15V), error amplifier, and a current-limiter circuit. The reference voltage (pin 6) is connected to the non-inverting input of the error amplifier (pin 5). The output voltage is sensed and reduced to 7.15V by divider R5, RV1, and R4. The output of the divider (wiper of RV1) is connected to the inverting input of the error amplifier (pin 4).

When the output voltage is low, the error amplifier output (pin 10) goes more positive. The error amplifier output is connected to the gates of the MOSFETs via resistors R2, R3, and R4. These low value resistors suppress oscillation of the MOSFETs and are located close to them. The output of the LM723 is emitter follower and can't sink current to turn the MOSFETs off. R7 provides a load to discharge the gate capacitance of the MOSFETs and turn them off. C5 provides feedback compensation.

If it is too small, the circuit may become unstable. If it is too large, the output may over — or under-shoot with load changes. The LM723 current-limiting circuit reduces the output when the voltage between pins 2 (current limit) and 3 (current sense) exceeds 0.6V. This is normally sensed by a resistor in the output current path.

The value for a 20A limit is 0.6V/20A = 0.03 ohms.



■ FIGURE 1.

Voltage Overhead in Bipolar Design

The traditional linear regulator circuit utilizes bipolar transistors. This results in a significant voltage overhead for correct operation. Overhead or dropout voltage is the additional input voltage above the regulated output voltage that is required for correct circuit operation. For higher current designs, this is composed of the regulator overhead and the pass element overhead. The LM723 overhead is a fairly substantial 3V (typical three-terminal 78xx regulators are 2V and some low dropout types are less than 0.2V).

The popular choice for pass transistors is the 2N3055 bipolar. For 20 amps output, at least two in parallel (probably four, but the number does not affect this analysis) with a third as a driver in a Darlington configuration is appropriate. The 2N3055 has a base-to-emitter voltage of 1.5V at higher currents. Adding 1V for the driver gives 2.5V. Additionally, the bipolar design needs emitter current balancing resistors. These are normally sized to drop 0.5V or more. Therefore, our total overhead is
3 + 2.5 + 0.5 = 6V. So, the minimum voltage at the input to the regulator is six volts higher than the desired output voltage.

This is all wasted energy converted to heat. For our 20 amp reference design, this is 6V x 20A = 120W. Some reduction could be made by having a separate supply for the regulator and driver. This could lower the overhead on the high current supply to 3.5V (3V output transistor collector emitter saturation voltage plus 0.5V balancing resistors). However, the regulator supply would itself have to be rated at two amps to drive the pass transistors.

For our 13.8V reference design, we need a minimum unregulated voltage of 19.8 volts to ensure correct operation. This equates to a 15.2V AC transformer without any allowance for line voltage drops or other losses. Typically, these designs use a 18V AC transformer. With 18V AC, this is our worst case power dissipation. This increases the power dissipation to around 228 watts for 276 watts of output power. This is less than 55% efficiency. The MOSFET design with a 15V transformer achieves 66% with a smaller transformer. Both these figures include the same bridge rectifier loss of 24W.

This is low for readily available resistors. In this design, the inherent resistance of the cable between the MOSFET source connection and the output terminal is used. This gives a poorly defined short-circuit current, but protects the MOSFETs. Any sustained overload will cause the mains fuse to fail. If an ammeter is fitted, it is included in the short-circuit sensing path.

Component Selection

A toroidal mains transformer was chosen as they are compact, cool running, and have low magnetic and audible hum levels. This example was based on a common stock size with a 15V output — 300VA. This will provide 20 amps AC (300V/A divided by 15V), however, as we are using a full-wave bridge rectifier and capacitor filter we cannot take 20 amps DC.

The simple explanation is that the DC voltage is equal to the peak of the AC or 1.4 x 15V = 21V. To maintain the same power in the transformer, we must divide the current by the same factor; 20A / 1.4 = 14A. This is slightly optimistic but is usable for most applications where full load is not drawn 24/7.

For 24/7 applications, a factor of 1.75 should be used. This will give an output current of 11.4A for a 300VA transformer. The specified transformer is made by Antek (**www.antekinc.com**).

The bridge rectifier is a 35A 200V PIV rated unit. While a 25A bridge will work, there are advantages using the 35A. The main advantage is lower voltage drop due to lower internal resistance. The specifications indicate 40% more current for the same 1.1V drop for the 35A bridge over the 25A, or a voltage drop of 200 mV less at 20A. That's four watts! The cost difference is minimal.

The main filter capacitor is an important component, particularly if there is a small difference between regulated and unregulated voltages. If the capacitor is too small or low quality, the smoothing will be inadequate. This causes a "ripple" at twice the mains frequency on the power supply output. Conversely, if it is excessively large, high peak currents will flow in the transformer and bridge rectifier causing overheating. So, how do we choose?

There are "rules of thumb" such as "1000 µF per amp of load," but there is a more calculated approach. In 1943, O. H. Schade published a paper "Analysis of Rectifier Operation" in the *Proceedings of the IRE*. Schade worked for RCA and the paper was about tube rectifiers. However, it contains formulas and charts for calculating filter capacitor values. These are based on the source (transformer and rectifier) and load resistance ratio, and the relationship of capacitor impedance at the ripple frequency to the load resistance. This is expressed as $2\pi fCR$ (C in farads, R in ohms). For 50 Hz mains (UK, worst case) the ripple is 100 Hz, so for 20,000 µF and a 0.8 ohm load (17A) $2\pi fCR = 5$. I chose 17A as it's between the continuous and intermittent loads.

The source resistance is not normally quoted for transformers but can be inferred from the change in output voltage from minimum load to full load (regulation). The 300VA toroidal has a measured regulation of 9%; 0.09 x15V = 1.3V at 20A. Ohms Law gives us an equivalent resistance of 1.3/20 = 0.065 ohms. I'll round up to 0.07Ω to allow for lead resistance. This gives a source/load resistance ratio of .07 / 0.8 = 0.09.

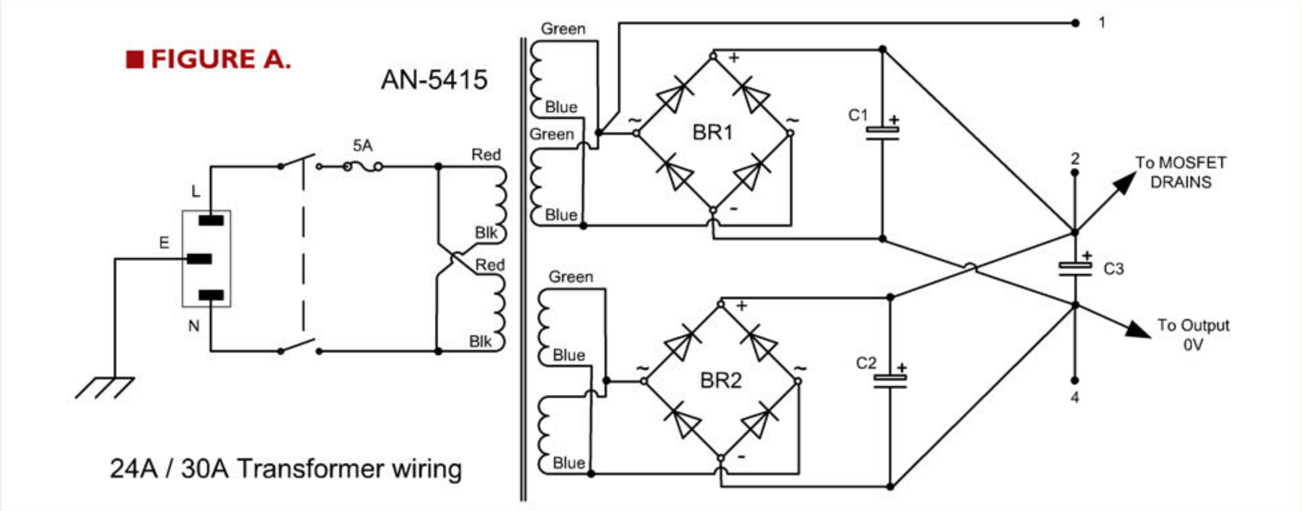
Schade's graphs give a ripple of 15% or about 3V with a 20,000 µF capacitor. This gives a minimum unregulated voltage of 16V, so we have a couple of volts in hand before ripple appears at the output at 17 amps. The voltage rating should be at least the peak off-load

More Power

A limit to maximum current with toroidal transformers is the thickness of wire that the automated winding machines can handle. This limit is typically 10A per winding; hence, the choice of a 300VA transformer for the basic design. However, Antek makes a standard 500VA, 15V transformer (part No.AN-5415) with four secondary windings. This gives the option to build a 24 amp continuous 30A peak variation of the basic design. The changes are two 35A bridge rectifiers, three 10,000 µF capacitors, and four IRF540 transistors rather than one, two, and three respectively.

The rectifier and filter capacitor arrangement is shown in **Figure A**. Note that this is two separate parallel winding and capacitor circuits paralleled at the third capacitor. The resistance of the interconnecting wires helps balance the currents.

FIGURE A.



24A / 30A Transformer wiring

transformer voltage: 15 + 9% x 1.4 =22.9V. The minimum rating is 25V.

Another important specification is ripple current. This is the maximum AC current the capacitor has to handle. A rule of thumb is twice the load current; 30A in this case. The theoretical maximum is the AC ripple voltage divided by the impedance of the capacitor at 120 Hz (USA worst case) and the source impedance in series. This is $3/(1/2\pi fC + Rs) = 3/0.133 = 22.5$A.

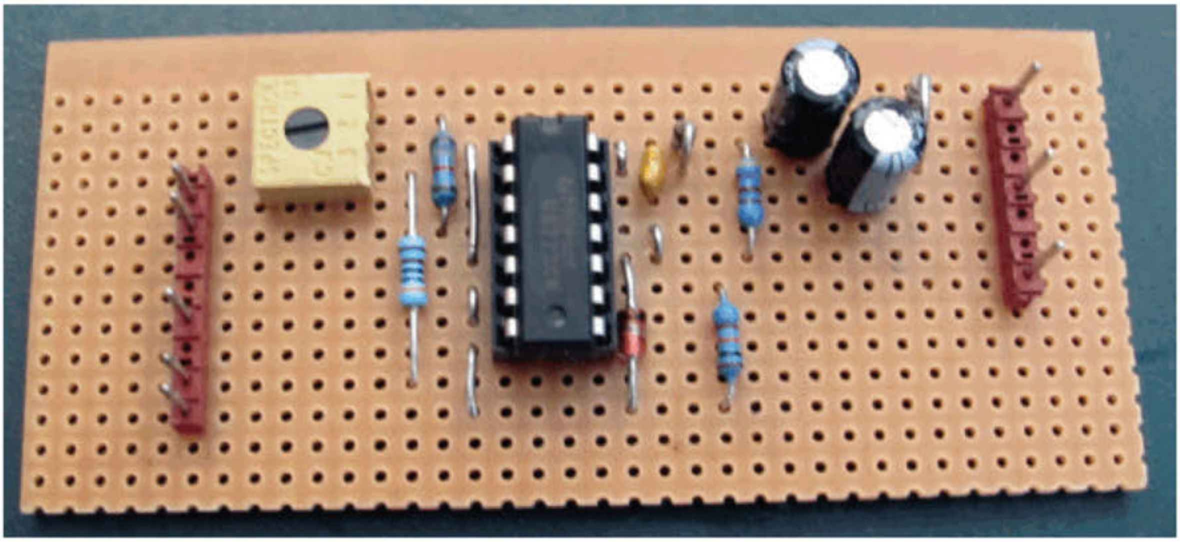
Using a capacitor with a lower ripple current rating will cause internal heating and early failure. The rating is related to size. Higher rated capacitors are larger. An alternative to a high rated capacitor is to use two or more lower rated units in parallel. The larger "computer grade" capacitors with screw terminals are preferable. This is one area where a surplus or hamfest component can be used to advantage.

If electrolytic capacitors have not been used for some

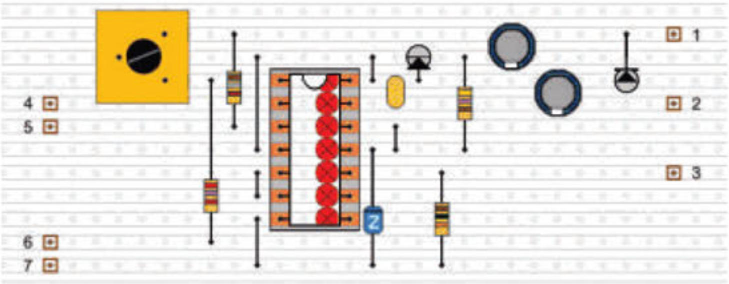
PARTS LIST

ITEM	PART # / DESCRIPTION	NEWARK#	TYPICAL COST	QTY
BR1	35A 200V Bridge Rectifier GBPC3502	58K8886	$2.30	1
C1,C2	10,000 µF 35V SLPX153M035E7P3	97M5165	$2.95	2
C3,C4	47 µF 50V EEU-FC1H470	17T5100	$0.1	2
C5	470 pF 100V Ceramic Capacitor MC0805N471J101A2.54MM	46P6575	$0.1	1
D1,D2	1N4002 1A 100V Diode	05R5979	$0.04	2
D3	1N4753A 36V 1W Zener	90R9440	$0.03	1
R1	470R 0.5W Resistor MFR4	97K4897	$0.07	1
R2,R3,R4	100R 0.5W Resistor MFR4	97K4822	$0.07	3
R5	10K 0.5W Resistor MFR4	83K8442	$0.07	1
R6	1K8 0.5W Resistor MFR4	78R4870	$0.28	1
R7	2K7 0.5W Resistor MFR4	78R4889	$0.28	1
TR1,TR2,TR3	IRF540N MOSFET	63J7319	$1.74	3
U1	LM723CN Regulator	41K6278	$0.87	1
VR1	3386F102 1K Preset	62J2090	$0.64	1
150AB1500MB or 325AB1000B	Heatsink	07WX4329	$22.87	1
		07WX4339	$6.44	3
MK3306	TO220 Insulator Kit	50P9593 Pack of 10	$2.57	1
Pomona 6883	Dual Binding Post	02J8383	$2.57	1
Antek AS3215	15V 300VA Toroidal Transformer		$41	1

■ PHOTO 1.



■ FIGURE 2.



time (years), it's a good idea to connect them to a variable supply via a current-limiting resistor (100Ω) and slowly increase the voltage from zero up to the full rated voltage over a few hours. This ensures that the insulating layer on the electrodes is fully formed.

Let's talk about pass transistors. These can be just about any N-channel power MOSFET with a Vds rating of at least 50V and a current rating of at least 15A in a TO220 package. Power rating is important as the MOSFETs are in linear mode and dissipate excess voltage as heat. With 20V unregulated, 13.8V out, and 20A load, the dissipation is 124W (20V-13.8V x 20A). My preferred device is the IRF540N. This is rated at 100V, 33A ,130W, and 175°C.

At first glance, it would seem that one of these will do the job. Scrutiny of the datasheet reveals that the 130W rating is at a case temperature of 25°C. This is virtually impossible using a practical air cooled heatsink. The MOSFET must be de-rated by 0.87W for each degree rise up to 175°C. So, that's 175-25 x 0.87 = 130W de-rating. We can dissipate 130W at 25°C or 0W at 175°C.

For a "reasonable" 65°C case temperature, one IRF540 can dissipate a maximum of 95W. However, this requires a heatsink of 40°/124W = 0.32°C/W, which is large. A hot 87°C and two MOSFETs requires a smaller 0. 5°C/W heatsink, but only allows 76W per MOSFET. This is too close for comfort, so we will use three IRF540s in our design. This gives 99A current rating and good short-circuit protection.

Another advantage of using multiple MOSFETs is that it spreads the heat input to the heatsink over a larger area and more insulating washers, resulting in lower MOSFET temperatures.

Construction

The case used is a matter of choice. Aluminium or steel construction is preferred for safety and strength. If a plastic case is used, extra care should be taken to ensure adequate heatsinking, ventilation, component mounting, and grounding. Line switches with metal toggles should not be used with non-metallic panels. I used an old lab instrument case — complete with mains inlet, fuse holder, and switch. The hardware from a failed commercial supply could be used.

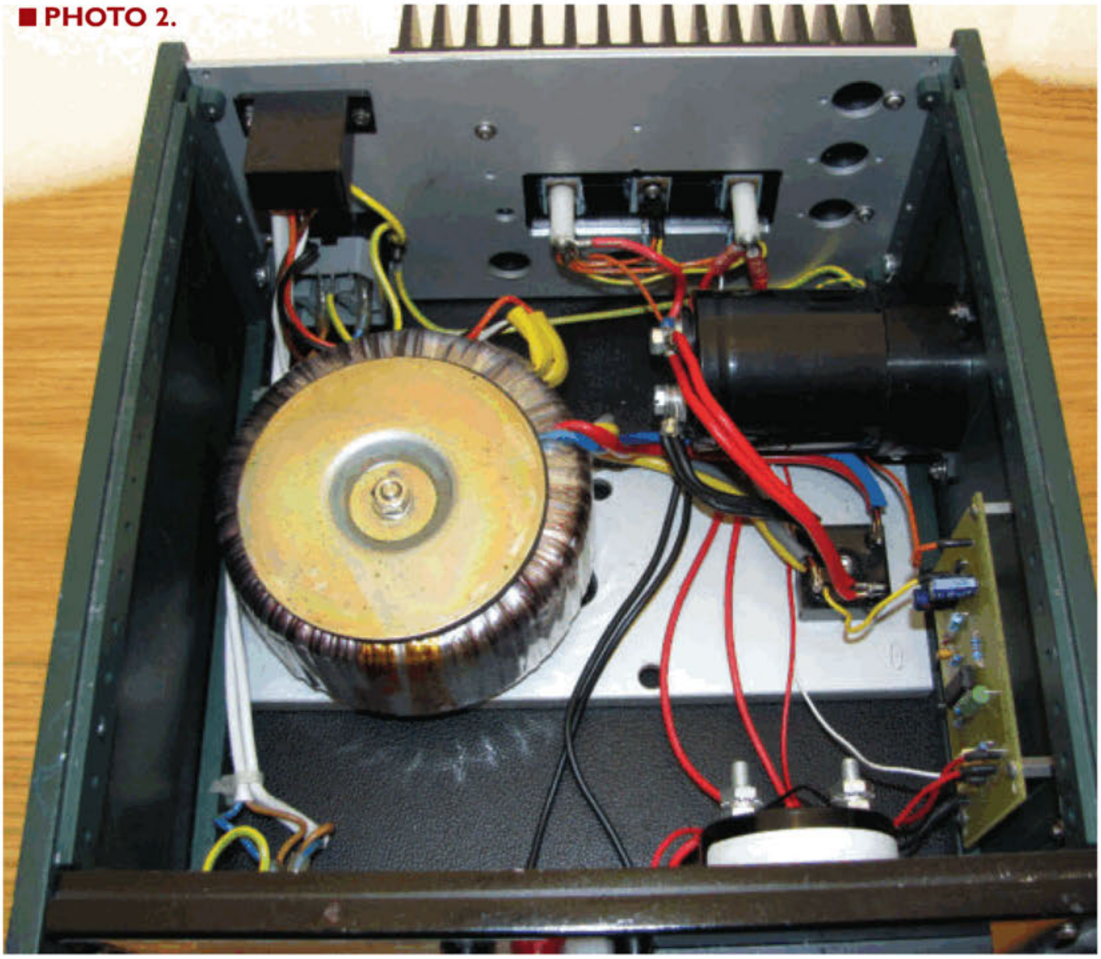
A grounded three-conductor mains cord MUST be used. Any exposed metal parts (e.g., case and heatsinks) must be connected to mains ground. Do not use the top of the toroidal transformer mounting bolt as an earth connection as this will create a shorted turn and damage the transformer. I recommend using an IEC C14 style line inlet. These are the type commonly found on PCs and can be purchased with an integral fuse holder and/or switch.

If used in a noise or RF critical application, a mains filter may be beneficial as may a 0.1 μF capacitor across the output terminals. The transformer has dual primaries and should be connected to suit your supply voltage. The fuse should be a 3.15A (115V, use a 1.6A for 230V mains) anti-surge (slo-blo) ceramic bodied type such as a Littelfuse 215P or Bussmann S505. Glass bodied fuses should not be used. All mains connections should be insulated. If you are not sure of any aspect for the line (mains) wiring, seek advice from a professional or experienced builder.

All low voltage power wiring should be as direct and short as possible. This particularly applies to connections between the transformer, bridge rectifier, and filter capacitors. Trim the transformer fly leads to length and solder them directly to the rectifier tabs — two fly leads per tab. Do not use push-on terminals.

The peak current in this circuit is higher than the DC output current. If the leads are enamelled copper, the enamel must be removed to get a good joint. Some enamel is self fluxing and will vaporize when hot enough to solder. Others will have to be removed by sanding or scraping. Practice on an off cut if you've not done this before. Don't nick the copper.

■ PHOTO 2.



Internal low voltage power wiring is either 14 AWG (2.5 mm²) or 2 16 AWG (1.5 mm²) wires in parallel. The parallel combination can be easier to handle and has slightly lower resistance. All 0V power connections should all be taken to a single point — preferably the filter capacitor negative terminal. All other components are standard parts available from many suppliers. Newark (**www.newark.com**) stock numbers are in the parts list. The control circuit is simple enough to be built on a prototyping board. A suitable layout is shown in **Figure 2** and **Photo 1**.

Photo 2 shows the internal construction of my prototype. I used a single 20,000 µF capacitor as it was available.

The tabs (Drain) of the MOSFETs are connected to the unregulated supply they must be insulated from the heatsink. Thin mica washers with heatsink compound have less thermal resistance than the dry elastomeric types. Take care if using computer type heatsink compound as some are electrically conductive.

The heatsink surface under the MOSFET should be clean, flat, and free of burrs — especially around the mounting hole. Use "top-hat" insulating washers on the screws. To achieve the full rating, a total of 0.5°C/W heatsinking is required. Less can be used, but beware of excessive temperatures if fully loaded for long periods.

Three individual heatsinks (one per device) of 1.5°C/W can also be used. This is another area where surplus or junk box parts can be put into action. Ensure the fins or slots of the heatsink are vertical so the heated air can flow upwards. A smaller heatsink can be used if supplemented with a fan.

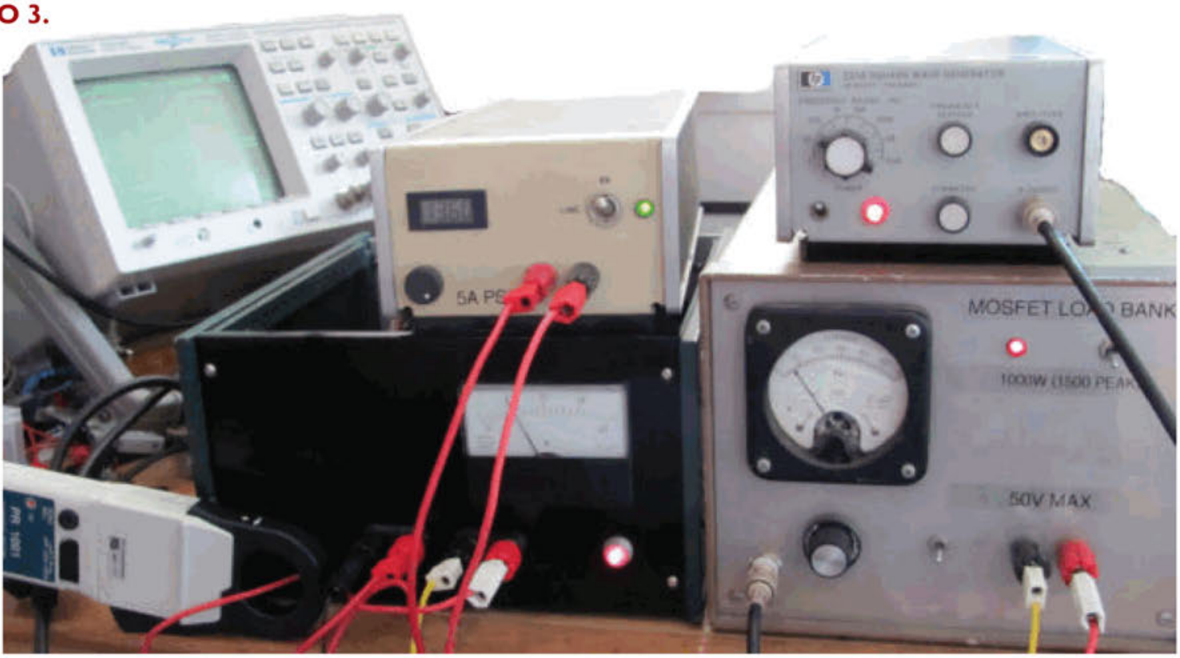
The bridge rectifier also requires heatsinking. This can normally be provided by the metal case of the power supply or a small heatsink of about 5°C/W.

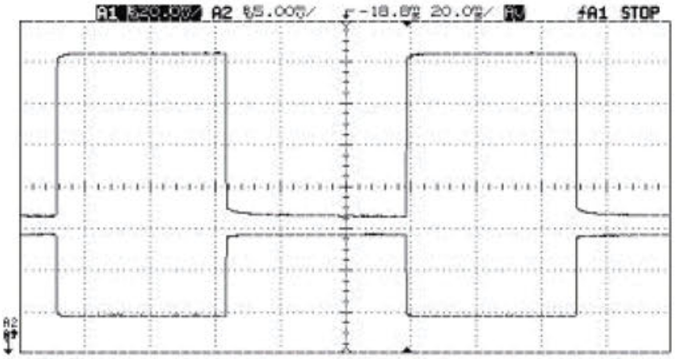
Performance Testing

As this is a new circuit topology and optimized design, full testing was carried out. This level of testing is not required for those replicating the design. The test setup can be seen in **Photo 3**.

It consists of the power supply, an electronic load that switched by a square wave generator, DC current clamp, oscilloscope, and a second DC power supply. The square wave generator and load were set to switch between zero

■ PHOTO 3.



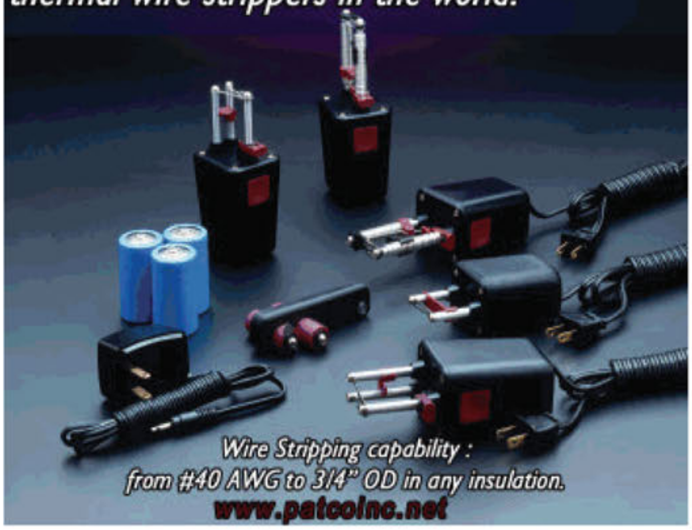


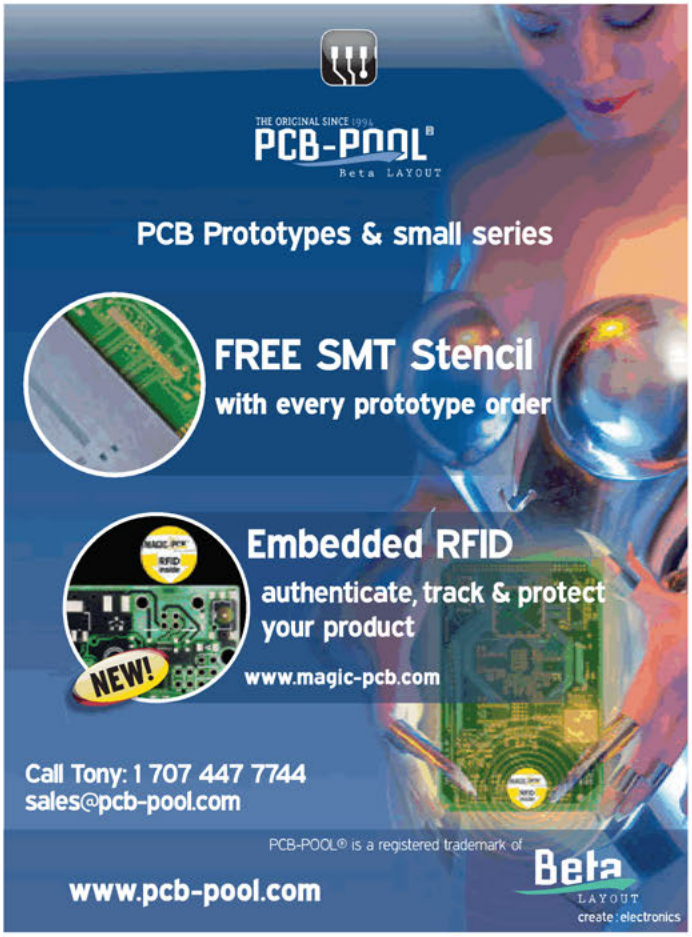
■ FIGURE 3.

and 10 amps at about 1 Hz. Channel 1 of the 'scope monitors the output voltage offset by the second power supply to allow higher sensitivity with DC coupling. Channel 2 monitors the current clamp output at 1 mV /amp. The resulting waveform is shown at **Figure 3**.

This shows a total output voltage step of 80 mV with no discernible overshoot or ringing. This is 0.6% and excellent performance. Most of the regulation error is the first 100 mA or so. A step from 140 mA to 14A gave a 30 mV drop or 0.25%.

I hope you find this power supply as helpful as I do. **NV**





AN EASY TWO-WIRE LCD

By Thomas Henry
studs.kreitzer@gmail.com

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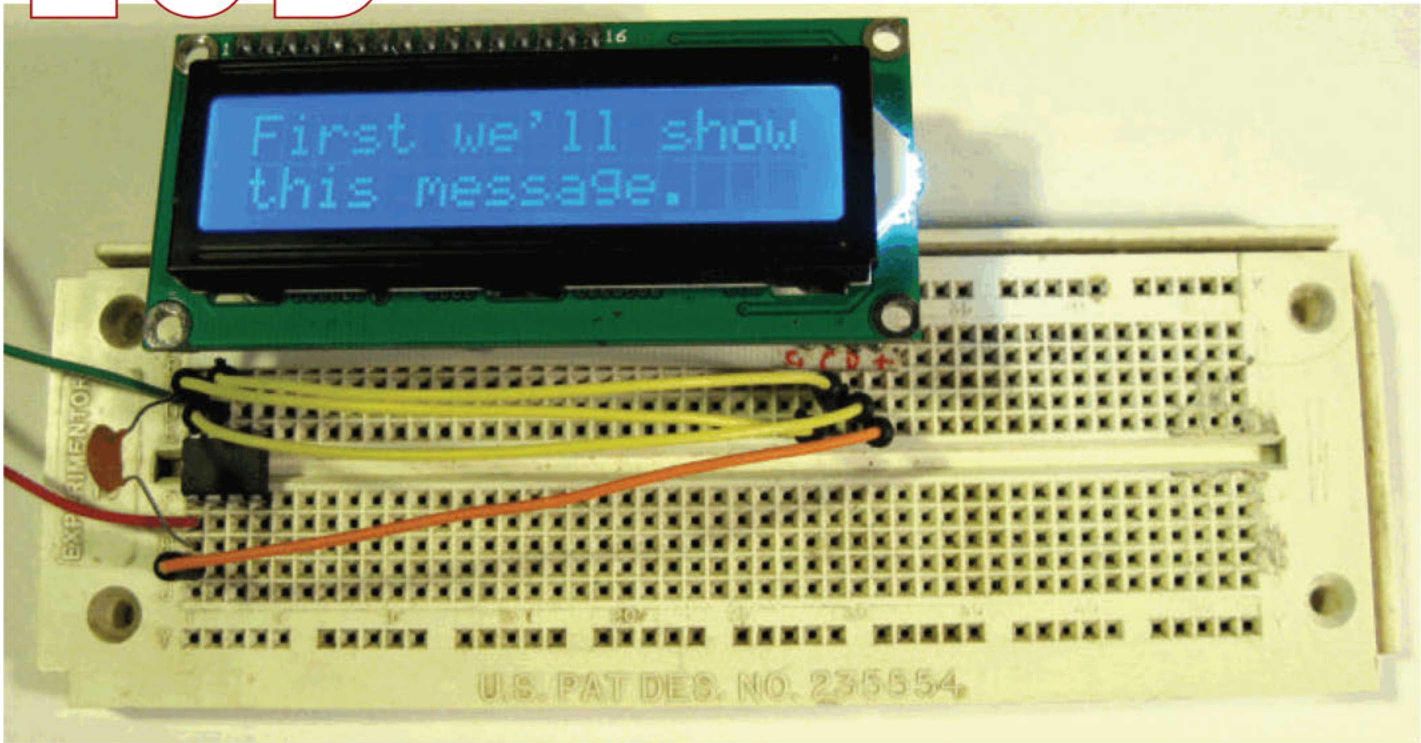


When getting started with microcontrollers, you'll quickly discover just how common it is to run out of available port lines. This is especially true when interfacing to parallel devices such as the common LCD (liquid crystal display). Inexpensive LCDs show up all the time on the surplus market, but these usually require either four or eight data lines in addition to several control lines. Of course, you could always dip into your wallet and spring for more advanced displays featuring I^{2}C or SPI serial inputs, reducing the wiring considerably. On the other hand, with just a pittance of external parts it is easy to reconfigure even the humblest LCD to run well on only two port lines of the microcontroller. This article describes just such a technique you can readily incorporate in your own designs.

Why would you really want to roll your own? There are several very practical reasons. First, as intimated above, parallel LCDs are ridiculously cheap nowadays, and with just a handful of inexpensive components you'll get the best of two worlds. Then again, not all microcontrollers support the I²C or SPI protocols should you even be tempted to go that more expensive route. This is especially true with eight-pin chips — the very ones you're likely to need a reduced port line count for anyway.

Even better, we'll get direct software control over all of the neat visual features of the LCD — things like panning, scrolling, various types of cursors, custom characters, blinking, blanking, and lots of other things. Moreover, the methodology used here is important in such diverse applications as communications, electronic music production, data logging, and more, making this an excellent educational experience as well.

One last thing before we dig in: There are lots of designs kicking around that get the serial interface down to three wires. I wanted to go one better and reduce it further. In particular, two wires only are all we need to make the LCD respond reliably. If your curiosity is aroused, carry on and let's see how it works.

Building Blocks and Pinouts

You've probably already deduced what the miracle ingredient is: a serial-to-parallel converter integrated circuit. I decided on the common and inexpensive 74HC595 which I picked up online through Amazon. **Figure 1** shows the pinout and also gives a feel for what to expect.

Let's look at the key features. A single bit (either a zero or a one) is placed on pin 14 — the serial data input. When a low-to-high transition is applied to pin 11, that bit is clocked in to the first stage of the shift register, but only after all other bits are bumped ahead one notch to make room for it. The current contents of the shift register are still "invisible." If, however, a clock signal is next applied to pin 12, then the presently concealed contents are latched into an external storage register and appear on the associated output pins.

So, the steps are (a) put a bit on the serial input; (b) strobe the shift register clock; and (c) strobe the storage register clock to make the bits appear on the outputs. By carrying these steps out eight times in a row, an entire byte coming in serially is moved bit-by-bit down the conveyor belt and finally appears on the output pins, Q_A through Q_H. If, for some reason, you'd like to clear everything out and start with all zeros again, a high-to-low pulse on pin 10 will accomplish that.

We won't need most of the other pins (except for power, obviously) and will worry about the details when we get to the **schematic**.

Figure 2 shows the pinout for a typical LCD. Most of these are set to operate either as eight-bit or four-bit parallel devices, but the latter is more than fast enough for any application I've ever come up against. So, we'll jettison pins 7 through 10 at once simply by grounding them. Anytime we need to send a byte to the device, we'll do so in halves, transmitting one nibble (four bits) at a time.

74HC595 Pinout

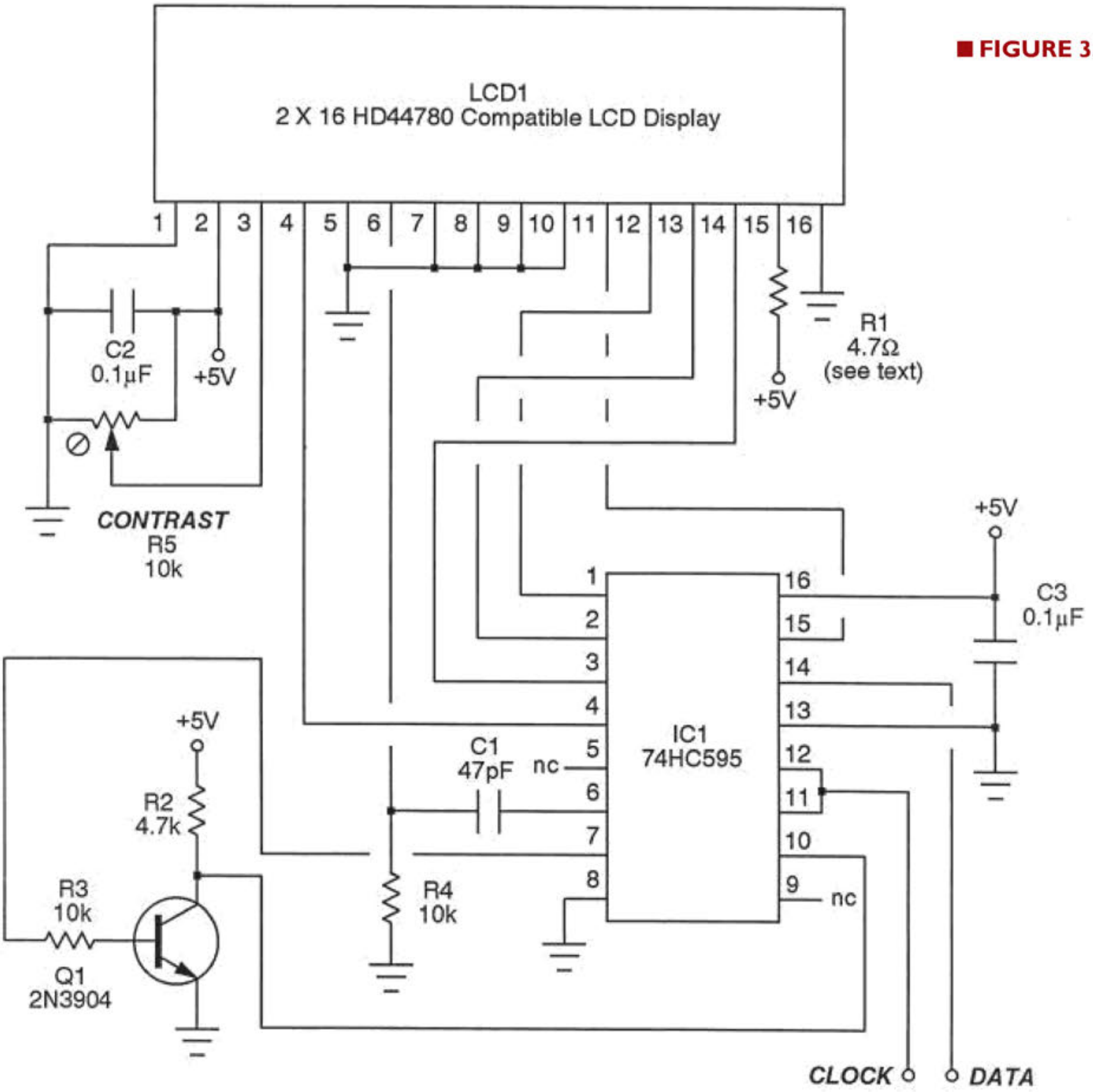
Pin	Symbol	Function
1	Q_B	output B
2	Q_C	output C
3	Q_D	output D
4	Q_E	output E
5	Q_F	output F
6	Q_G	output G
7	Q_H	output H
8	GND	ground
9	Q_H'	output to next stage
10	$\overline{\text{SRCLR}}$	shift register clear
11	SRCLK	shift register clock
12	RCLK	storage register clock
13	$\overline{\text{OE}}$	output enable
14	SER	serial data input
15	Q_A	output A
16	V_{CC}	supply voltage

■ FIGURE 1.

LCD Pinout

Pin	Symbol	Function
1	GND	ground
2	V_{CC}	supply voltage
3	V_O	contrast
4	RS	register select
5	R/W	read/write
6	E	enable
7	D0	input 0
8	D1	input 1
9	D2	input 2
10	D3	input 3
11	D4	input 4
12	D5	input 5
13	D6	input 6
14	D7	input 7
15	A	backlight anode
16	K	backlight cathode

■ FIGURE 2.



■ FIGURE 3.

LCDs do have the ability to talk back, but that feature is almost never required. So, we'll also ground pin 5 which is the Read/Write line. This is a one-way street.

It is possible to send either a command or a character to the LCD. Commands take care of such things as clearing the screen, homing the cursor, and so forth. Characters are indicated by means of the ubiquitous ASCII code set. To let the display know what the incoming byte (or more accurately, pair of nibbles) represents, use pin 4 – the Register Select (RS) line. When this is low, the byte stands for a command; when high, it is a character.

Once either a command or character has been placed on the data lines, a quick low-to-high pulse on the Enable line (E) at pin 6 locks it in. A pulse width of a couple microseconds will do the trick.

The few remaining lines are fairly pedestrian in nature and will be explained once we get to the complete circuit. At this point, you have a basic understanding of the pins of both the 74HC595 and the LCD at your fingertips. As you'll see, it's remarkably easy to mate the two parts. So, let's cut at once to the gestalt!

How They Go Together

Figure 3 shows the schematic for a complete working circuit, consisting more of wires than anything. Let's chase them down. Outputs Q_A through Q_D of the 74HC595 connect to data inputs D4 through D7 of the LCD, respectively. Recall that inputs D0 through D3 are grounded and not needed for four-bit operation. Output Q_E of the chip drives the Register Select input of the LCD. Output Q_G feeds the Enable input of the LCD, but only after being processed by C1 and R4.

You can think of this RC network as being a differentiator if you want, or else as a half-monostable if that term is more comfortable. The purpose is simply to make sure the eventual Enable strobe is shorter than the actual signal appearing on Q_G.

IC1 output Q_H is first inverted by transistor Q1 and then fed back to IC1 to provide a reset or clear operation. The inversion is necessary since the shift register clear pin expects negative logic. If you already have an uncommitted inverter kicking around in your design, you can use it instead and then eliminate Q1, R2, and R3.

Output Q_F is not needed and is simply left unconnected. Output Q_H' (note the prime symbol there) is also left floating. This pin is normally employed when ganging several of the chips for more bit outputs.

The shift register clock and storage register clock lines (pins 11 and 12) are tied together and simply become the clock input. When configured in this manner, the storage register (the latch outputs, in other words) will always be one step behind what's happening internally within the shift register.

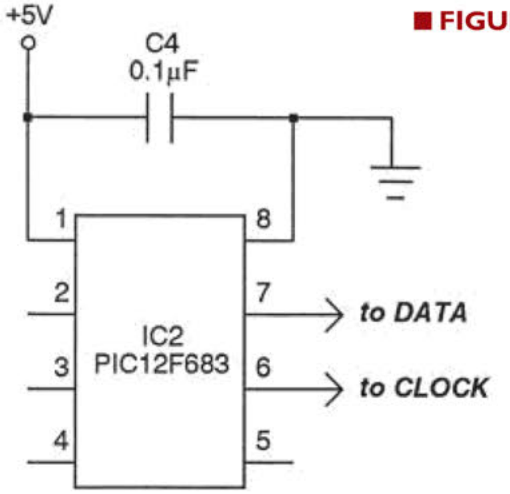
The serial data input is found at pin 14 of IC1. Pin 8 is ground, while pin 16 is +5V. Pin 13 is also grounded to enable the tri-state outputs of the 74HC595.

Back to the LCD. Pin 3 is used to set the contrast of the display; connect it to a potentiometer or trimmer. Pins 15 and 16 take care of the backlight LED, if any. Some units require a resistor as shown in the **schematic** (R1), while others need a power rectifier. Use whatever the datasheet for your particular LCD specifies.

Lastly, pin 1 is the LCD ground, while pin 2 is +5V. For reliable operation, it's very important to straddle these with a 0.1 µF disc capacitor.

■ FIGURE 4.

	Reset	Enable	not used	Register Select	D7	D6	D5	D4	
0	0	0	0	0	0	0	0	0	Register
	0	0	0	0	0	0	0	0	Latch
1	0	0	0	0	0	0	0	1	Register
	0	0	0	0	0	0	0	0	Latch
2	0	0	0	0	0	0	1	0	Register
	0	0	0	0	0	0	0	1	Latch
3	0	0	0	0	0	1	0	RS	Register
	0	0	0	0	0	0	1	0	Latch
4	0	0	0	0	1	0	RS	D7	Register
	0	0	0	0	0	1	0	RS	Latch
5	0	0	0	1	0	RS	D7	D6	Register
	0	0	0	0	1	0	RS	D0	Latch
6	0	0	1	0	RS	D7	D6	D5	Register
	0	0	0	1	0	RS	D0	D1	Latch
7	0	1	0	RS	D7	D6	D5	D4	Register
	0	0	1	0	RS	D0	D1	D2	Latch
8	1	0	RS	D7	D6	D5	D4	0	Register
	0	1	0	RS	D7	D6	D5	D4	Latch
9	0	RS	D7	D6	D5	D4	0	0	Register
	1	0	RS	D7	D6	D5	D4	0	Latch
10	0	0	0	0	0	0	0	0	Register
	0	0	0	0	0	0	0	0	Latch



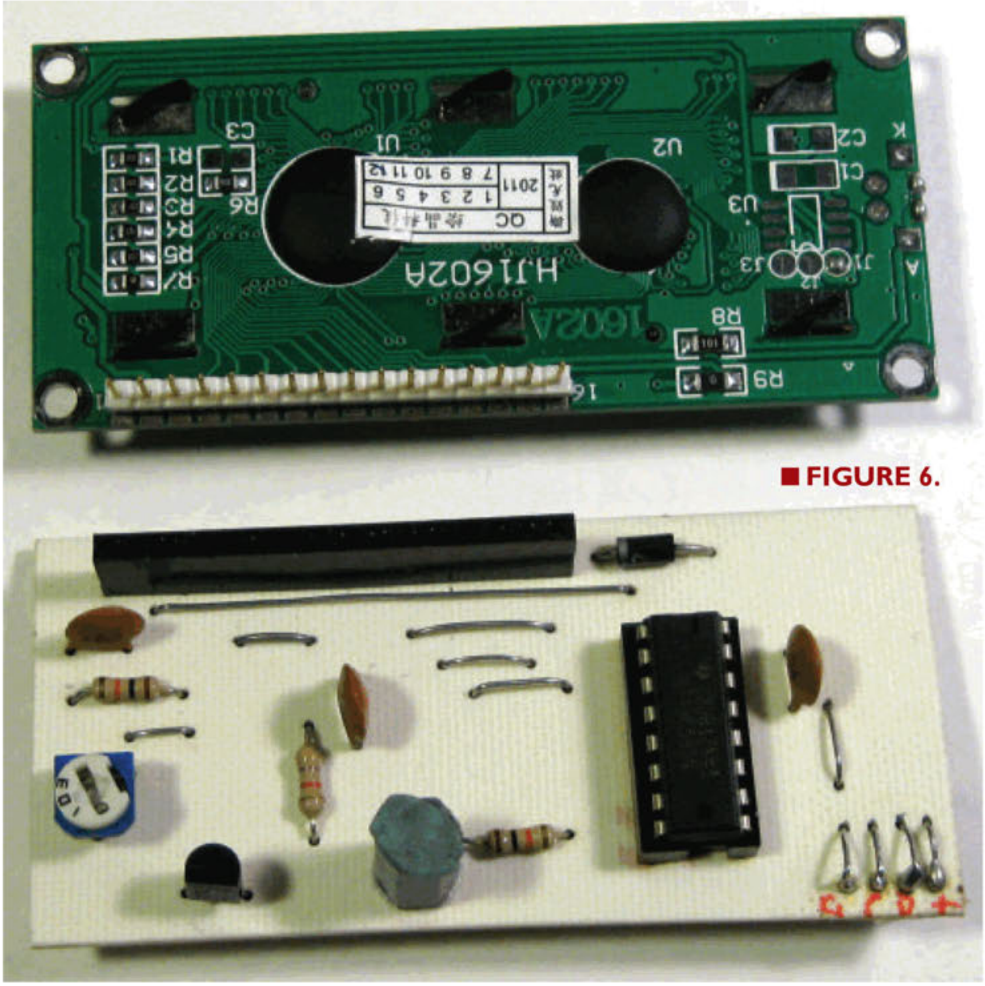
■ FIGURE 5.

The Grand Dance

With the hardware out of the way, it's now time to choreograph the flow of bits. Obviously, this will be handled by the microcontroller you choose to use. Let's not worry about the actual code here, but instead focus on what has to happen and when. **Figure 4** shows the road map.

Now, don't panic because the progression displayed there is very linear in nature, as you'd expect in serial-to-parallel conversion. The steps are labeled 0 through 10. Furthermore, each row is split in two, showing what the shift register currently holds and what the storage register (called the latch from now on) is presently outputting to the LCD. Don't forget that the latch is always one clock pulse behind the shift register. Let's see what happens.

At the outset (Step 0), both the register and the latch are clear; this is the normal condition during quiescence. In Step 1, a one is input. This will eventually first become the enable pulse in Step 8, and then the reset pulse in Step 9.



■ FIGURE 6.

In Step 2, a zero is fed in. Its purpose is to bring the Enable pulse low again in Step 9.

Step 3 pumps in the RS bit — either zero for a command or one for a character. By the time we get to Step 8, it will obviously be controlling the RS line going to the LCD.

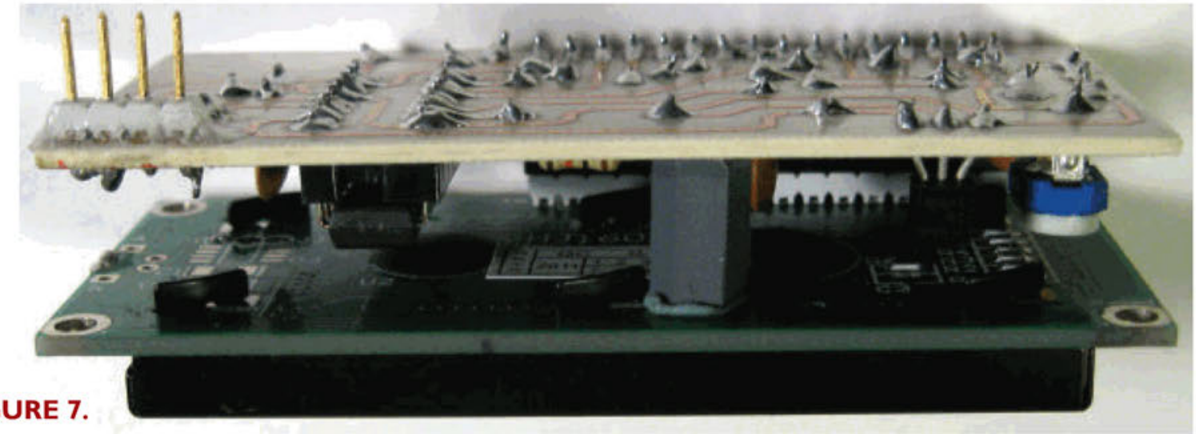
Steps 4 through 7 shift in the four data bits comprising a nibble — a pair of which will eventually make up an entire command or character byte. Keep pulsing the clock away and in time, the bits will arrive at their desired positions.

Now, Step 8 is where the action really occurs. Data lines D0 through D4 are in place, as are the RS and Enable bits. The data is locked in to the LCD here. Then in Step 9, the Enable line goes low once more, followed by a reset a split second after that. The 74HC595 is forced to an all-clear state in Step 10, which is back where we originally started.

Thanks to the software download for this article, you don't really have to know all of the ins and outs. Nonetheless, it really is instructive to work through the steps with a pencil in your hand, just so you learn how a shift register works.

The Software

Just to show what's all possible with this rig, I put together a complete software package consisting of a demonstration program along with the necessary drivers. This has been implemented for the popular PIC12F683 microcontroller which is, in fact, an eight-pin device just



■ FIGURE 7.

About the Software

Like many modern electronics projects, this one depends a fair amount on software components as well. Fortunately, all of the programs required here are absolutely free of charge. Let's start with the firmware for the PIC microcontroller.

Go to the article link and download the package for this article. In it, you will find source code for the drivers and a complete program demonstrating just about everything an LCD can do. The code is written in the excellent Great Cow Basic language. The nice thing here is that this language supports parameter passing and program structures like procedures and functions, so all the routines are just lying there ready for you to pluck for your own work. If you feel the need, you can even port the code over to an existing commercial Basic language like PICBasic PRO, since the syntax is virtually the same. In any event, the drivers contain routines for sending nibbles, and complete commands and characters, along with a set of equates for unlocking all of the other features in an LCD.

You can download an absolutely free copy of the Great Cow Basic compiler from **www.gcbasic.sourceforge.net**. There are no restrictions and no hidden catches.

The download package for this article also contains everything you need if you'd like to build the piggy-back module I described. In particular, you'll find .pdf files of the printed circuit board (PCB) artwork and a parts placement guide, along with the complete original file. This has been created with FreePCB — an exceptionally fine PCB design package. As the name suggests, it too is completely gratis. You'll find it at **www.freepcb.com**.

The PCB was designed as a double-sided affair which could certainly be sent to a professional etching facility. Since the only top-side traces are straight lines, I actually etched my own single-sided board and simply installed jumper wires on top. It was quick and easy, and works very well.

PARTS LIST

Passive Components

R1	4.7W (see below)
R2	4.7K
R3, R4	10K resistor
R5	10K trimmer
C1	47 pF disc capacitor
C2, C3	0.1 mF disc capacitor

Semiconductors

Q1	2N3904 NPN transistor
LCD1	2 x 16 LCD display
IC1	74HC595 shift register

Note: The backlight in an LCD typically requires something to drop the voltage a bit. In the unit shown here, R1 was specified. Sometimes, however, a rectifier is used. Check the datasheet for whatever LCD you employ.

begging for a two-line LCD. It's simple enough to change it over to any other PIC or, for that matter, port the entire software to just about any other controller you have in mind. Look to the **sidebar** to learn how to get the source code.

Figure 5 shows the circuitry for the PIC12F683 and how to connect it to the two-line LCD. Not much to it, is there? So, give it a try. Compile and assemble the code, and then Flash it to the microprocessor. Upon power-up, you will be treated to a demonstration of all sorts of things that are possible such as blinking, scrolling, panning, extended character sets, and more.

A Stand-Alone Package

One final thing before I turn you loose to come up with your own application. I thought it might be handy to have an all-in-one arrangement for the two-wire LCD. To this end, the download package for this article also includes the printed circuit board artwork to make a piggyback affair for most any LCD you bump into. It's been designed to permit easy connection to a solderless breadboard during testing stages of circuits incorporating the two-wire LCD.

Figure 6 shows both a typical LCD, along with the piggyback board implementing this circuit. **Figure 7** shows what it looks like when the two are snapped together, while **Figure 8** shows the entire rig on a breadboard, shining away.

So, let's hear no more of that all-too-common groan, "I've run out of port lines!" **NV**

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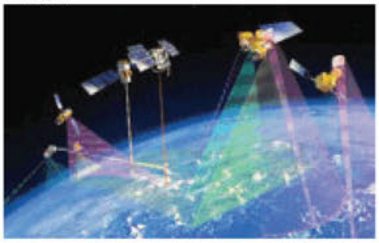

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AN ARDUINO CONTROLLED DIGITAL FM RADIO

By Craig A. Lindley
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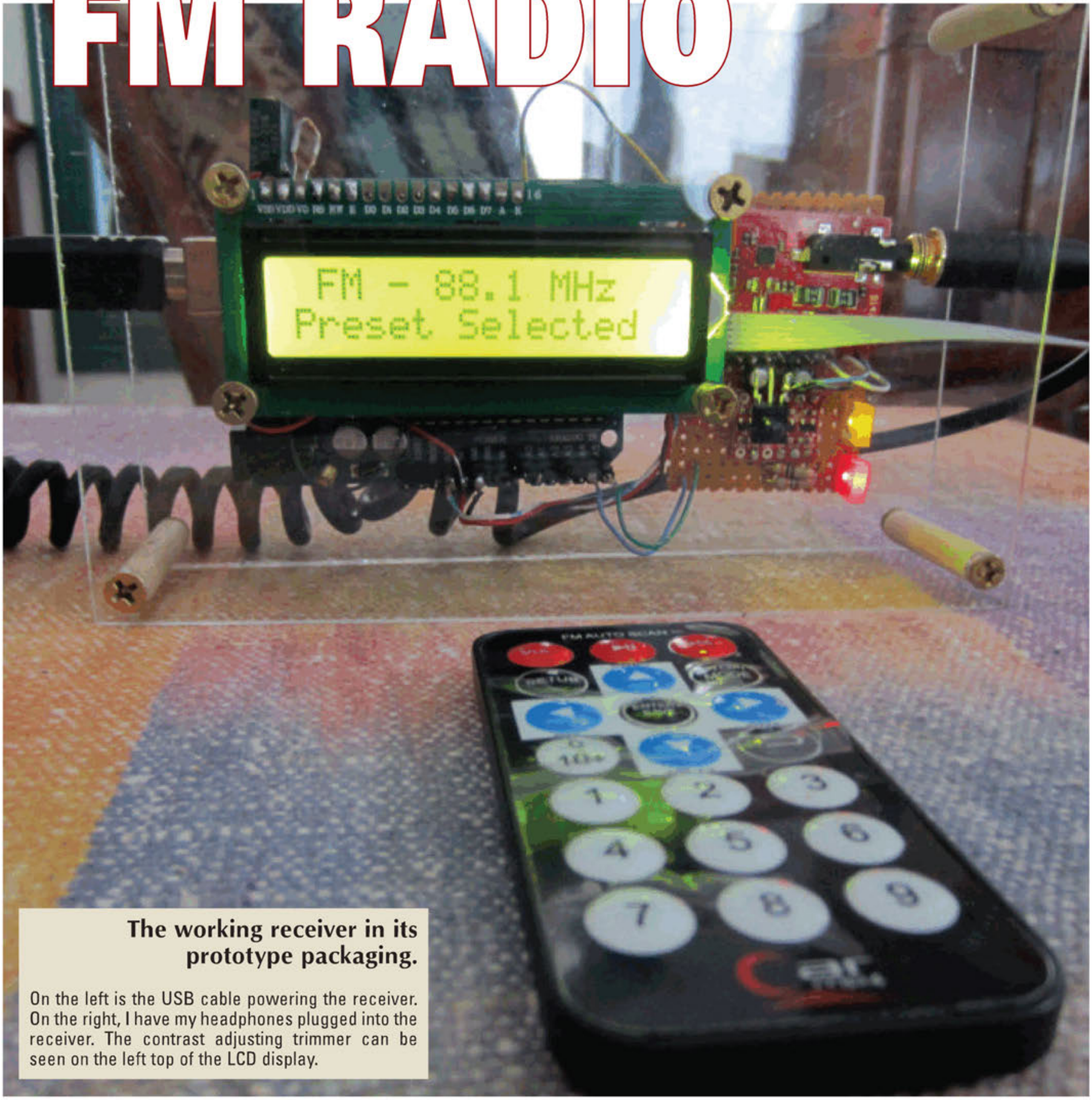


The working receiver in its prototype packaging.

On the left is the USB cable powering the receiver. On the right, I have my headphones plugged into the receiver. The contrast adjusting trimmer can be seen on the left top of the LCD display.

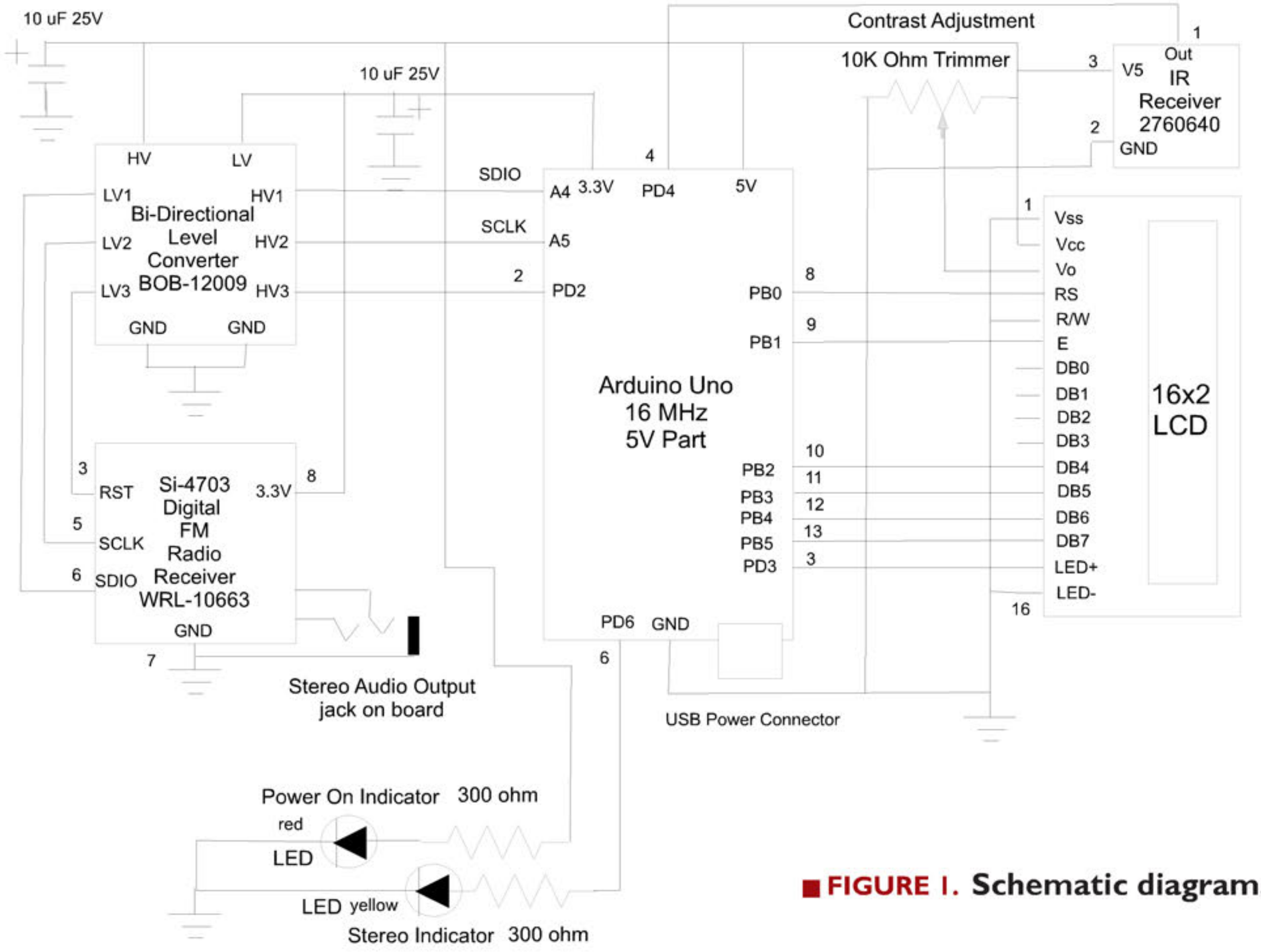
I'm always on the lookout for cool new (at least new to me) hardware components that I might incorporate into one of my electronic/computer projects.

Recently, while shopping online at **SparkFun.com**, I came across an evaluation board for a digital FM receiver about the size of a postage stamp that sparked (no pun intended) my interest. Having grown up listening to FM radio, I thought it would be fun to build an FM receiver of my own design. While this may seem to some as a very retro project (what with Internet radios, music players, and smartphones surrounding us), it has turned out to be quite useful. Now, I have a remote controllable FM radio that I listen to with headphones while I am working. It sits on my desk alongside the Desktop Contemplator and the Unique Digital Clock that I have written about previously. My desk is becoming cluttered with all the useful projects I have designed and built.

While I listen to my FM radio/receiver with headphones, it can just as easily be plugged into a stereo amp with speakers to provide sound for a whole room. The fidelity of this receiver is quite good when tuned to strong FM stations. Because of its compact size, you could even incorporate this FM receiver into a boom box of your own design.

This project can be built by anyone with basic electronic assembly and schematic reading experience. The software is somewhat complex, but is made simpler by the use of pre-existing libraries for the major hardware components. The Arduino Uno sketch (program) for this FM receiver project is available with the article downloads. Because you have access to the source code, you can make changes to the design and/or add new features to the receiver. If you come up with a cool new feature, please email me the code so I can incorporate it into my receiver/radio, as well.

Let's begin by discussing the hardware. Software will be discussed a little later.



■ **FIGURE 1. Schematic diagram.**

Hardware

The hardware is built around an Arduino Uno board running at 16 MHz and five volts. I've been finding these boards on eBay for around $13 each, so I bought a few. Other Arduinos could be used, but some of the I/O pin assignments might need to change. Using an Arduino running at a different clock speed will also impact the design, especially in the IR (infrared) detection area. None of these problems are insurmountable but you will be in uncharted territory if you deviate from the design presented here.

I initially planned to have physical controls on the FM receiver — a power switch, a rotary encoder for channel selection, and a couple of pushbuttons for mode selection — but I quickly realized that I would then need physical proximity to the receiver to manipulate it. I then thought adding IR remote control would be interesting but soon realized that if I added that, the other physical controls would be redundant and unnecessary. In the end, I decided to go the "no control" route, so all of the receiver's functionality is controlled through an IR remote. Quite convenient really.

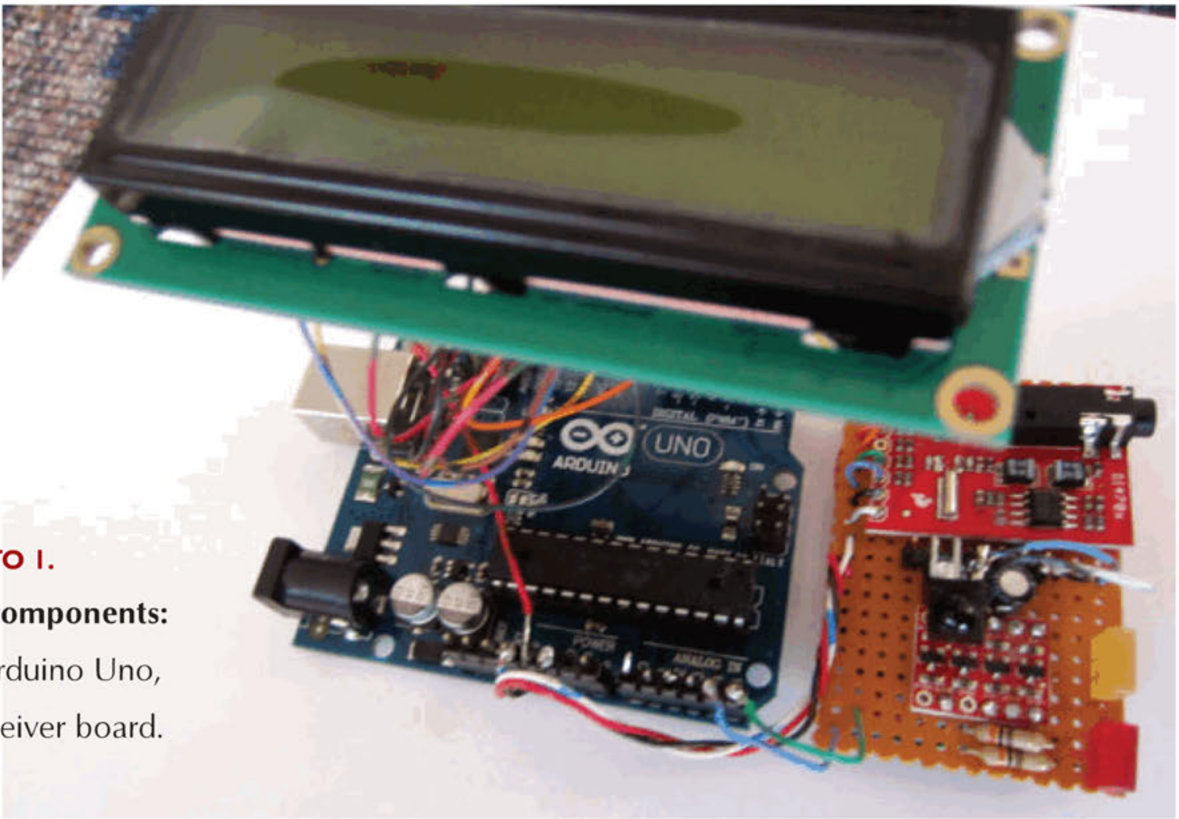
While not technically a control, there is a contrast adjustment for the LCD display which should be set once and left alone. I used a 10-turn screw driver adjustable trimmer, but any 10K to 20K ohm potentiometer could be used in its place.

A schematic of the hardware is shown in **Figure 1**. I built my radio using point-to-point wiring (can you say rats nest?), but a prototyping shield could be used for a cleaner build.

The LCD display provides a four-bit parallel data interface to the Arduino, while the Si4703 FM receiver is connected to the Arduino via an I^{2}C interface. Since the Arduino Uno is a five volt part and the FM receiver is a 3.3 volt part, a bi-directional level converter must be used between them. The LCD display also runs on five volts. The backlight for the LCD display is directly controlled by an output pin from the Arduino.

The stereo audio output cable is used as the antenna for the FM receiver, so you must pay attention to the length of the interconnect. The cord on the headphones I use works fine as an antenna since I can pick up all of the FM stations in my area.

When strong stations are tuned in, the audio quality is top notch. When the receiver is receiving a stereo broadcast, the yellow stereo indicator LED lights up.



■ PHOTO 1.

Three components: LCD, Arduino Uno, and receiver board.

Weaker stations are received in mono and the stereo indicator remains dark. A red LED lights when the radio is on.

An IR receiver (which is what RadioShack called it) is used to detect IR codes from the remote control. It filters out the 38 kHz IR carrier frequency from the received signal, thereby making detection of the key codes more straightforward. The radio is powered via a USB cable and a USB power supply. Alternatively, the radio can be powered by connection to a USB port on your computer. There is no power switch. If you want to power-down the radio, unplug the USB cable and/or power supply.

Wiring and wire routing for this project are non-critical. Be advised that as with all digital circuitry, keeping the wires as short as possible/practical is always a good idea. Using a consistent color scheme for the wires is also recommended. I used red for five volts, white for 3.3 volts, and black for all ground connections. Various other wire colors are used for data and clock signals.

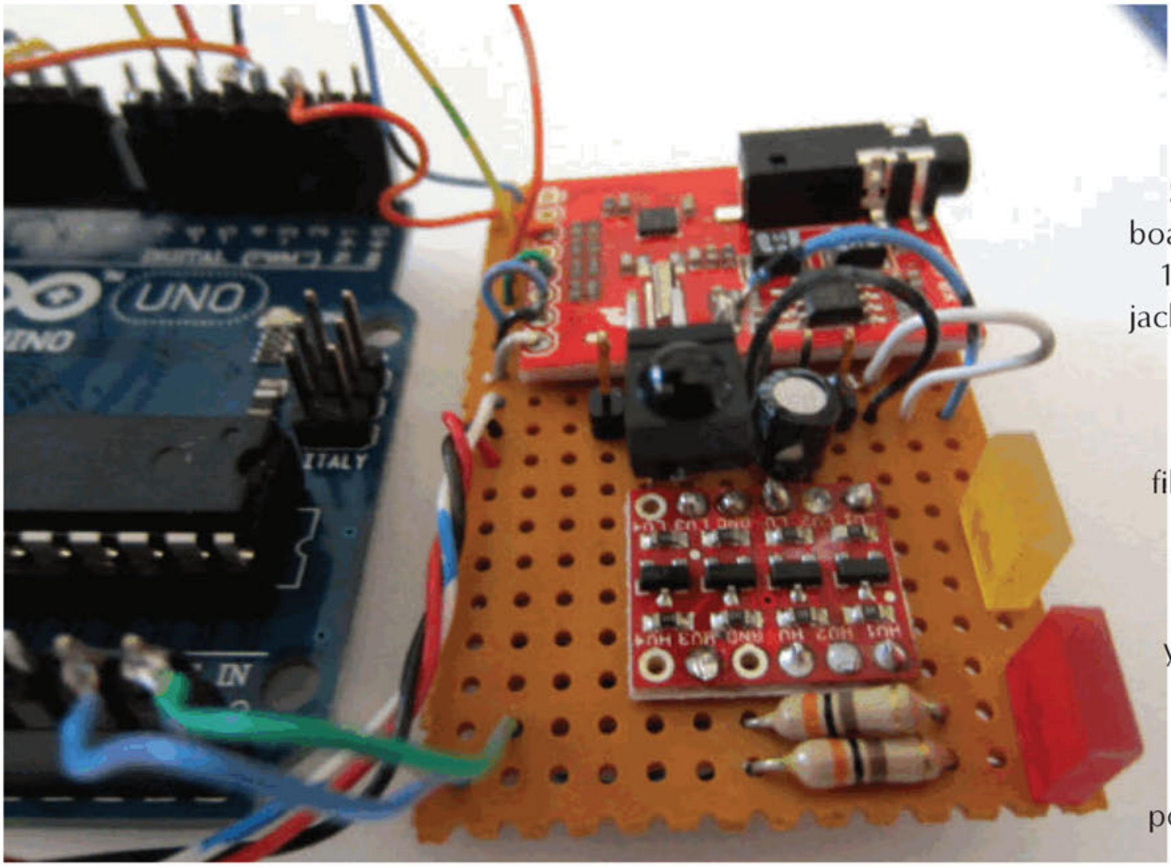
Packaging

I packaged my radio using two 4" x 6" pieces of clear 1/8" acrylic plastic in a sandwich-like arrangement, held together by wooden 1-1/2" dowel spacers in the corners. I like the naked electronics look. The LCD display is mounted to the front acrylic piece and the Arduino Uno and receiver board are mounted to the rear piece. The finished radio is free standing with this packaging approach. Check out **Photos 1** and **2** for details.

Software

All of the radio's software was developed using the Arduino IDE (Integrated Development Environment) version 1.0.5 for OSX. Windows version of the IDE is available if that is your chosen computing environment. Make sure you have the board type set to Arduino Uno and the serial port set appropriately in the IDE. Of course, you will need to plug the receiver's Uno into your computer via a USB cable to download the provided firmware via the IDE.

Three libraries are used in this project to ease the software development task: the Liquid Crystal library which comes standard with the Arduino IDE; an IR remote library for IR code detection; and a library for controlling the Si4703 digital FM receiver. The **Resources** section has pointers/links as to where these libraries can be obtained.



■ **PHOTO 2. Receiver board close-up.** At the top is the Si4703 evaluation board with the black 1/8" stereo output jack. In the middle is the IR receiver facing upward, along with some filter caps. Towards the bottom is the four-channel level converter; the yellow rectangular LED is the stereo indicator and the red LED is the power-on indicator.

■ **PHOTO 3. IR mini remote control.**

The Liquid Crystal library is preinstalled when you download the IDE, so you need not do anything else to use it other than including *LiquidCrystal.h* in your sketches. To install the IRremote library, you must first unzip the downloaded IRremote library file somewhere on your computer and then copy its contents to your arduino\libraries directory. Finally, rename the Arduino-IRremote-master directory to IRremote and you should be good to go.

Installing the Si-4703_Breakout library is similar. First, download the library, unzip it, copy its contents to the arduino\libraries directory, and then rename the directory called Arduino-Si4703-Library-libcode-only to Si4703_Breakout.

The Arduino IDE must be shut down while installing new libraries. Once restarted, the IDE should pick up anything newly installed. You can check for proper installation by clicking Examples from the File menu. There you should see an IRremote entry with a bunch of example sketches, along with a Si4703_Breakout entry with its example sketch.

Whereas the Liquid Crystal and the IRremote libraries can be used as-is, the Si4703_Breakout library must be modified before being used in our application. This library was not built with the idea that someone might want to extend it with functionality the library didn't directly provide.

For our application, I needed the ability to mute/unmute the FM receiver and to poll the stereo reception indicator — functionality the library doesn't provide. Luckily, the change to the library is trivial and only involves editing the header file (*Si4703_Breakout.h*). Again, the Arduino IDE must be shut down while editing is being performed. Bring up *Si4703_Breakout.h* in a text editor of some kind. On my Mac, I use TextEdit; on Windows, you could use Notepad.

The change involves moving the following entries from the private section of the interface definition up to the public section.

Once you have moved these four lines of text, save the file, and we should be ready to go:

```
void readRegisters();
byte updateRegisters();
int getChannel();
uint16_t si4703_registers[16];
     //There are 16 registers, each 16 bits large
```

With this change, we are able to extend the functionality of the Si4703 library as required for our application.

Software Overview

You may want to refer to the *DigitalFMRadio.ino* sketch during this discussion.

The sketch is broken up into numerous sections for organizational purposes. At the top of the sketch are the global definitions, followed by the hardware definitions where all of the I/O pins for the radio are assigned. Following that, there are sections for the major hardware elements of the design in the following order: IR Receiver, the LCD display, the Si4703 FM receiver, EEPROM, and finally, miscellaneous functions. Following that are the *setup()* and *loop()* Arduino functions.

In the IR receiver section, an instance of IRrecv called *IrReceiver* is declared and assigned the IR_RECEIVER_PIN defined earlier. This assignment connects the IR receiver hardware to the software that will manage it. Next, the IR remote control key codes for the AdaFruit remote (see

Photo 3) are declared. I listed all of the key codes available from the remote control — not just the ones used in this sketch.

Finally, two convenience functions are defined which wrap functions in the IR receiver library for ease of use.

In the LCD section, an instance of LiquidCrystal called *lcd* is defined and is passed to the hardware I/O pins used in this design. Again, this connects the hardware to the managing software. A single function is then defined that will clear a specified row of the LCD display when called.

The Si4703 section is a little more complicated in that we have to extend the functionality of the Si4703_Breakout library. First, though, an instance of the library is created called *radio* that is passed to the I/O pins used in this design. The Si4703 FM receiver is controlled using a series of 16-bit registers. In a typical operation, the registers are read from the chip, values are changed, and the updated register values are sent back causing the receiver chip to react.

The function *updateStereoIndicator* is a little different in that we are only polling the status of the receiver to determine if a stereo signal is being received to determine if the stereo indicator LED should be lit or not. In the *muteRadio* function, we read the registers, set or clear the DMUTE bit (depending on whether or not we are muting), and then send the modified registers back to the chip.

The EEPROM section has functions for reading and writing eight- and 16-bit unsigned integers from the EEPROM contained within the Arduino's processor. Values written to the EEPROM survive loss of power and will be available indefinitely until changed.

The Miscellaneous section has functions for displaying the FM station frequency on row 0 of the LCD display; for displaying row 1 messages on the LCD display; for retrieving and storing FM station presets; and for processing presets. The *processSetPreset* function waits for an IR key to be pressed on the remote control and then stores the channel/station that is currently being listened to in a corresponding preset in EEPROM.

The Arduino *setup()* function prepares the hardware for operation. Here, the backlight, the power-on, and the stereo LED control pins are configured as outputs. The IR receiver is enabled, the LCD display is configured for 16 character by two row operation, some volume and channel defaults are installed, and the EEPROM is prepared for use.

To prevent bogus preset values from being used, I wanted to do a one time initialization of the EEPROM, setting each preset value storage location to zero. To make sure this is only done once, the code looks for a signature in the first two bytes of the EEPROM. If the

■ TABLE 1.

Key	Function
Vol-	Mutes the audio
Play Pause	Turns the radio off and on
Vol+	Un-mutes the audio
Up Arrow	Volume up
Down Arrow	Volume down
Left Arrow	Scan down for a station/channel
Right Arrow	Scan up for a station/channel
Enter Save	Sets up for saving a preset. Tune in the desired station, press Enter Save, and then a key (1 .. 9) to save the station as a preset.
Keys 1 .. 9	Tunes station if preset is set; otherwise, does nothing.

PARTS LIST

ITEM	PART #/DESCRIPTION	SOURCE
Arduino Uno	16 MHz Five volt part	SparkFun, AdaFruit, RadioShack, eBay
Bi-directional Level Converter	BOB-12009	SparkFun
Evaluation Board for Si4703 FM Tuner	WRL-10663	SparkFun
16x2 Line LCD Display	Any LCD noted to be Arduino compatible should work.	SparkFun, AdaFruit, eBay
IR Receiver	#2760640	RadioShack
Red LEDs		
Yellow LEDs		
2 x 300 ohm 1/4W resistors		
10K ohm 10-turn Trimmers		
2 x 10 µF @ 25V Capacitors		
Mini Remote Control	ID: 389	AdaFruit
USB Cable for Arduino to USB Power Supply Connection		SparkFun, AdaFruit, RadioShack, eBay
USB Power Supply 500 mA or greater		SparkFun, AdaFruit, RadioShack, eBay
.1" Male Breakaway Header Pins for Arduino connectors		SparkFun, AdaFruit, eBay
Wire, Solder, Packaging, etc.		

Resources

The following sites may be of interest to those seeking more information on the topics described in this article.

Information about the Si4703 digital FM receiver can be found at the manufacturers website at **www.silabs.com**. AN230, AN231, and AN243 are application notes concerning the Si470x series parts. AN332 provides example code useful for programmers.

The free Arduino IDE development tool for Windows, OSX, and Linux is available at **http://arduino.cc/en/Main/Software**.

The IRremote library is available at **github.com/shirriff/Arduino-IRremote**. There is a Download ZIP button in the lower right side of this page. Click it to get the library.

The Si4703_Breakout library is available at **github.com/infomaniac50/Arduino-Si4703-Library**. Again, click the Download ZIP button to get the library.

An AmForth version of the firmware is also available. Contract the author for details.

signature is not found, the two-byte signature 0xAA, 0x55 is written and all 10 preset locations are set to zero.

If the signature is found — which is usually the case — EEPROM initialization is skipped.

The Arduino *loop()* function is where the radio is controlled. It consists of a large switch statement that is driven by the key codes received from the remote control. **Table 1** details which keys do what.

It is important to note that when power is applied to the radio, it appears to be off even though it really isn't. Instead, the firmware is constantly looking for the Play Pause key code to be received to virtually turn the radio on. A variable called *radioOn* tracks whether the radio is off or on. The processing of all key codes is conditional on this variable since I didn't want the radio responding to commands while it was supposed to be off. Most cases have similar structure.

First, the *radioOn* variable is checked and if the radio is on, a function is performed and a message is written to the LCD display. If *radioOn* is false, the received key code is ignored. Processing of the Play Pause key is the most complex as numerous steps are necessary to virtually turn the radio off or on. The comments in the code should make it clear what is happening.

The cases used for retrieving a preset should be mentioned. There are nine presets available, numbered 1 through 9. When a preset key on the remote is clicked, the corresponding preset is retrieved from the EEPROM and its value is examined. If a value of zero is returned, the preset has never been set so the radio does not respond. If, however, a non-zero value is returned, that channel is set.

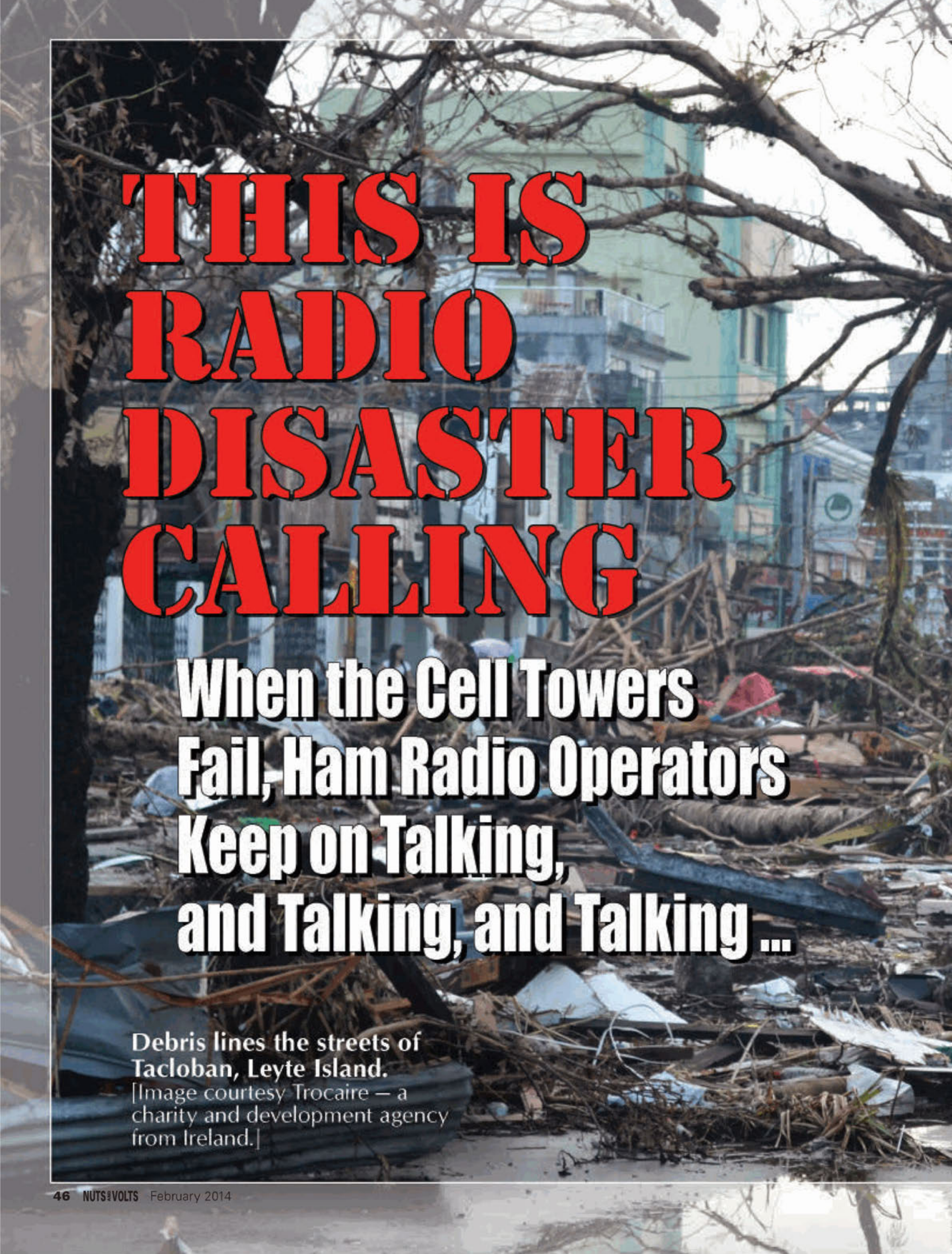
Preset 10 is a special case. When the radio is virtually turned off, the channel that was being listened to is written to preset 10. Then, when the radio is virtually turned back on, preset 10 is read and that station/channel is reinstated.

Conclusion

Building your own FM receiver is cool and easy — even if listening to FM radio the traditional way over the air seems retro. **NV**

THIS IS RADIO DISASTER CALLING

When the Cell Towers Fail, Ham Radio Operators Keep on Talking, and Talking, and Talking ...



Debris lines the streets of Tacloban, Leyte Island. [Image courtesy Trocaire — a charity and development agency from Ireland.]

Okay, the unthinkable just happened and you're totally cut off from all communications: no cell phones, no landlines, and no way of reaching out to the rest of the world. Who you gonna call?

Well, if you're prepared for disaster, then you just dust off your amateur radio transceiver, hook up your automobile battery for powering your equipment, and begin transmitting and receiving communications from anywhere in the world.

By Dave Prochnow

Post comments on this article at **www.nutsvolts.com/index.php?/magazine/article/february2014_Prochnow.**

Affectionately known as "hams," these radio operators (NOTE: A ham's equipment is also known as ham radios) are able to continue the flow of information to and from a disaster relief area within moments of any kind of emergency. Especially those types of emergencies where the normal lines of communication (i.e., cell phones) are either overloaded (e.g., Boston Marathon bombing) or gone (e.g., Hurricane Katrina).

Fueled by automobile batteries or banks of solar cells and bristling with VHF/UHF satellite and HF antennas, amateur radio operators are able to both get the word out of a stricken area and — more importantly — get the word *into* a disaster area. It is the flow of information that helps to minimize panic and assist in recovery.

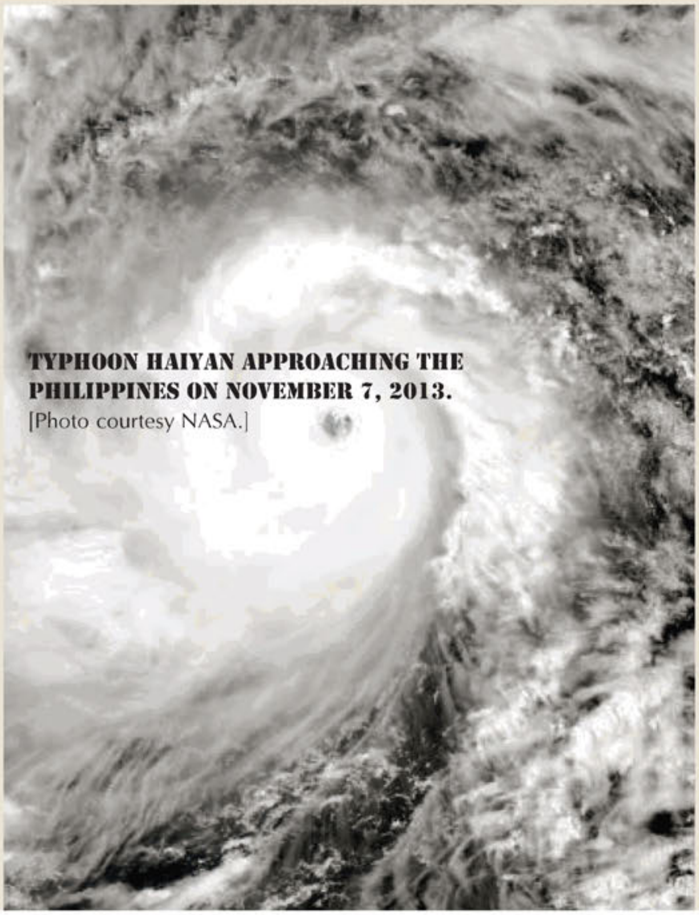
CQ, Anybody?

In this day of mobile telecommunications, it might be unknown to most people that amateur radio operators are a major communications backbone throughout the world. This involvement is no clearer demonstrated than in times of natural disasters. Looking strictly at the United States, ham radio operators are divided into several vital roles for providing communications during relief efforts.

The two more common disaster relief roles are through the American Radio Relay League (ARRL) Amateur Radio Emergency Service (ARES) and the Radio Amateur Civil Emergency Service (RACES). While the former is a private organization that lends a helping hand to the American Red Cross, Salvation Army (e.g., Salvation Army Team Emergency Radio Network), volunteer fire departments, and National Weather Service (for example, as storm spotters), the latter is a drop-in replacement communications service that is sanctioned by the FCC.

Regardless of which hat a ham is wearing, however, they are all linked together through a requisite membership within the scope of the national Amateur Radio Service.

Similarly, there is a strong support contingent of amateur radio



TYPHOON HAIYAN APPROACHING THE PHILIPPINES ON NOVEMBER 7, 2013.
[Photo courtesy NASA.]

According to the US Navy Joint Typhoon Warning Center, Typhoon Haiyan had maximum sustained winds of 195 mph (314 kilometers per hour), with wind gusts up to 235 mph (379 kilometers per hour) shortly before hitting landfall in the central Philippines. Weather officials in the Philippines reported the storm — known locally as Typhoon Yolanda — hit with maximum sustained winds of 147 mph (235 kilometers per hour) and gusts of up to 170 mph (275 kilometers per hour).

This Category 5+ storm that barreled through the Central Philippines in November 2013 left survivors without food, water, shelter, electrical power, and cell phone service. Springing into action, the Philippine Amateur Radio Association (PARA) immediately issued pleas for emergency communication equipment for supporting PARA's Ham Emergency Radio Operations (HERO) network. Designed to establish a presence in less populated and harder to reach areas, PARA conducted a painstaking solution to a logistical nightmare. Two weeks after the typhoon's landfall, PARA had successfully established a complex network of ham radio stations throughout the affected region.

What began with only one local PARA station — Lester, DV5PO, in the capital town of Borongan, East of Samar — quickly mushroomed into a network of makeshift stations. Beginning with a relief operation shepherded by Darwin Torres 4F1FZE (a veteran ham operator), PARA operators that provides operations as varied as involvement with the Federal Emergency Management Agency (FEMA) and the Department of Defense (DoD). Unlike the natural disaster response, the DoD support is during a national crisis with the Military Auxiliary Radio System (MARS) when ham radio operators are enlisted to provide emergency communications on restricted military radio frequencies (pursuant to invocation of the President's War Emergency Powers under the provisions of section 706 of the Communications Act of 1934, as amended, 47 U.S.C. 606).

The rules and regulations for governing these emergency radio procedures are defined in the FCC document Code of Federal Regulations (CFR) Title 47 — Telecommunications. Inside CFR 47 is Part 97, Amateur Radio Service. Deep within Part 97 is Subpart E — Providing Emergency Communications (97.401-97.407).

For more info see: **www.gpo.gov/fdsys/pkg/CFR-2010-title47-vol5/xml/CFR-2010-title47-vol5-part97.xml**.

In grossly simplified terms, there are three prime definitions that constitute "emergency communications:" (1) safety of life and protection of property; (2) station in distress; and (3) radio amateur civil emergency service (or RACES). Okay, that's a lot of government jargon, but what are the "real" actions required of ham radio operators during these times of crisis?

First and foremost, each operator is required to get his/her house and property in order. In other words, make sure everyone and everything you care about is safe and secure. Then — and only then — an amateur radio operator is required to report to work as an emergency communications operator.

Based on the training for each operator, there will be a set of primary frequencies that each ham is required to monitor. Other emergency personnel on these frequencies will provide the ham with instructions for either relay or implementation. At that point, the operator might have to relay some vital information "up the line."

With the radio set to its maximum power level, the amateur radio operator will say "Break, Emergency" and wait for a repeater station to respond. When he/she has acquired a repeater, an emergency autopatch system is activated for making 911 telephone calls.

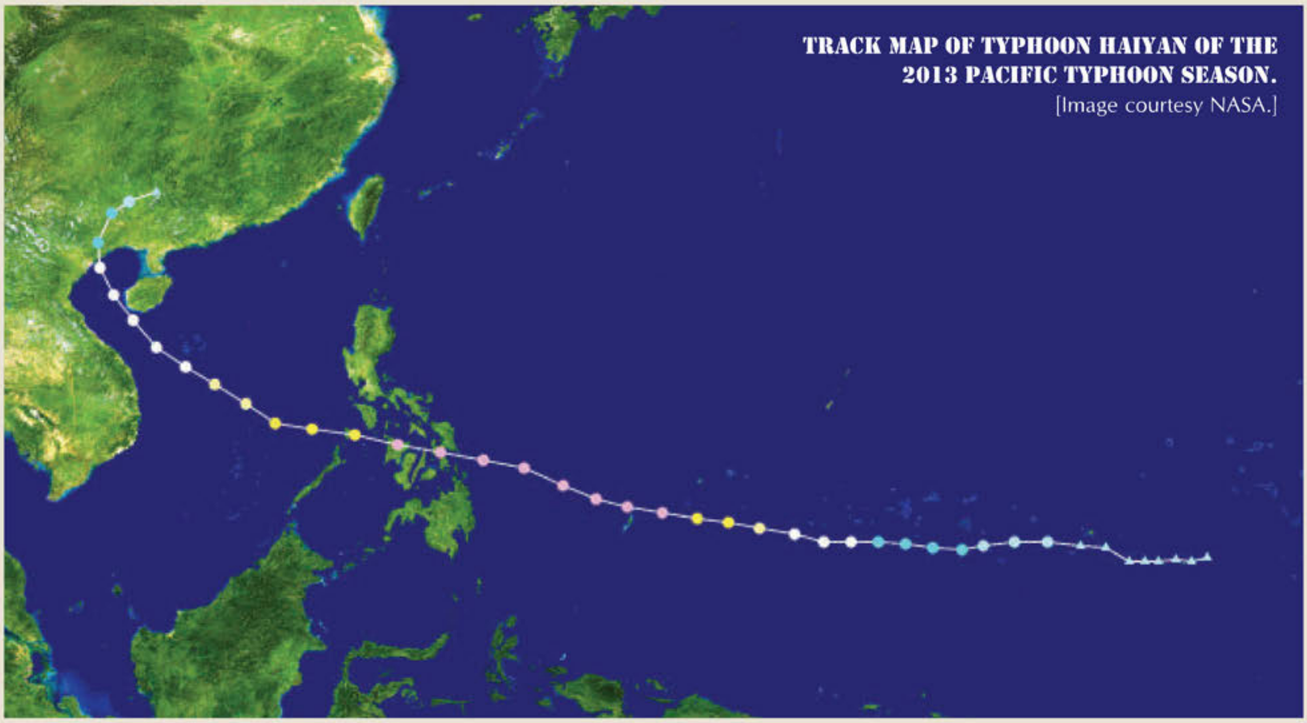
Once the 911 operator is connected, the ham will indicate that this is an emergency call that is being implemented through amateur radio. The remainder of this emergency call will proceed like a typical 911 cell phone call. At the conclusion of the transmission, however, the ham must release the autopatch.

QSL

"MAYDAY, MAYDAY, MAYDAY, this is ...," is the standard beginning for a station in distress call.

based operations in Tacloban. PARA then implemented a plan to improve VHF coverage over the area, with HF remaining a critical component.

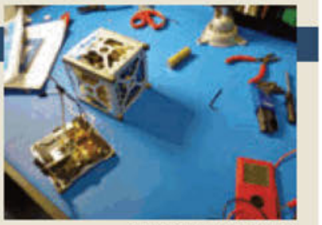
Using battery- and solar-powered repeater stations in Tacloban, teams were deployed to Samar, Guiuan, and further west linking Samar to Tacloban and vastly improving coverage over a significant piece of the area surrounding Samar.



TRACK MAP OF TYPHOON HAIYAN OF THE 2013 PACIFIC TYPHOON SEASON.
[Image courtesy NASA.]

Picture This!

ANTARES ROCKET CARRYING THREE PHONESATS READY FOR LAUNCH.
[Photo courtesy Orbital Sciences Corporation.]



PHONESAT 1.0 ASSEMBLY
[Photo courtesy NASA.]

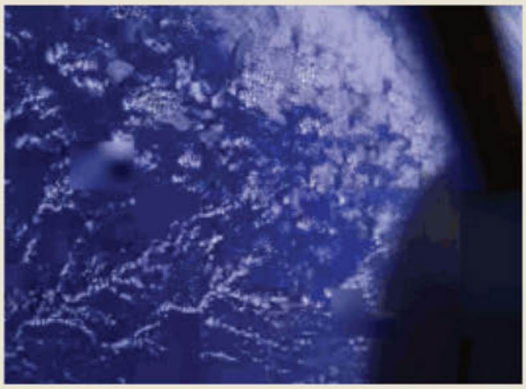
"GRAHAM" PHONESAT 1.0
[Photo courtesy NASA.]

The National Aeronautics and Space Administration (NASA) has long been a strong and avid supporter of amateur radio operators. From maintaining the Ames Amateur Radio Club station NA6MF, to successful collaborations between NASA and volunteer amateur ham radio operators from around the world, NASA is a world leader in enabling researchers and hams to work together as citizen scientists.

Case in point: A recent NASA mission enlisted the combined efforts of 100s of ham radio operators from around the world, on every continent, except Antarctica. This NASA "nanosatellite" mission — called PhoneSat — which blasted into space on Sunday, April 21, 2013 aboard an Antares rocket from NASA's Wallops Island Flight Facility in Virginia, contained three miniature satellites built around three commercial off-the-shelf (COTS) smartphones (e.g., Nexus One made by HTC Corp., running Google's Android operating system). The goal of PhoneSat was to determine whether COTS devices — like a smartphone — could be used as the main flight avionics system for a satellite in space.

The three satellites — named Alexander, Graham, and Bell — used their smartphone cameras to take pictures of Earth. These photographs were then transmitted as "image-data packets" to multiple ground stations. Each packet held a small piece of graphic data that contributed to "the big picture." As the data became available, the NASA PhoneSat Team and the volunteer amateur radio operators would piece together the data packets into a high-resolution photograph of Earth.

This collaborative effort was declared a success by Bruce Yost, program manager for NASA's Small Satellite Technology Program. "The PhoneSat project also provided an opportunity for NASA to collaborate with its space enthusiasts. Amateur radio operators from every continent (but Antarctica) contributed in capturing the data packets we needed to piece together the smartphones' image of Earth from space." The mission successfully ended Saturday, April 27, 2013 when PhoneSat reentered Earth's atmosphere and burned up. You can see the results from this mission at **www.nasa.gov/topics/technology/features/PhoneSat_PHOTO_feature.html**.



EARTH FROM "GRAHAM" PHONESAT 1.0
[Photo courtesy NASA Ames Research Center, Moffett Field, CA.]

Accompanying this prefix will be the latitude and longitude for the station, a description of the emergency, and a statement about what type of service is needed by the station. Depending upon the severity of the disaster, this call is repeated until either a reply is received or the station is out of danger.

In certain situations, the station might attempt to relocate its distress call to another frequency. Prior to changing frequencies, the station should indicate the new frequency that is going to be used before the change is made.

Adhering to this frequency change procedure will ensure that other stations who are listening to the distress call but can't be *heard* by the station in distress will be able to continue monitoring the crisis.

Conversely, operators who hear a distress signal must immediately begin recording the event. A time-stamp and frequency notation should be appended to this recording. The proper response to a distress call is to indicate the station's call sign that you received, along with your call sign, followed by asking the station's disposition. After this acknowledgement, the receiving station will be a relay for emergency action from 911, civil authorities, or DoD controllers, and will remain on the air until the emergency is resolved.

73

Believe or not, this system of radios, telephones, government regulations, operators, and hams really works during times of natural disasters. In fact, it works really, really well. Consider that in the aftermath of Hurricane Katrina, Congressional testimony exploring the government's emergency response to this disaster cited the use of amateur radio operators as one of the few bright spots in an otherwise lackluster relief effort. Likewise, despite the rise in social networks being used following the impact of super-storm Sandy in 2012, the overwhelmed cell networks were pushed into the background and ham radio operators were able to keep information flowing throughout New York and New Jersey.

Whether it's knowing about an impending storm threat, the site of a local water distribution center, or simply that someone "out there" cares about you, a large comprehensive communication network is vital when a disaster cuts you off from the rest of the world.

That's exactly what amateur radio operators do. They keep information going when the rest of our "modern" services are out. **NV**

2010 WPX SSB AT THE W7RN CONTEST STATION USING FOUR ELECRAFT K3S. [Photo courtesy Elecraft.]

NASA ASTRONAUT DOUG WHEELOCK, EXPEDITION 24 FLIGHT ENGINEER, USES A HAM RADIO SYSTEM IN THE ZVEZDA SERVICE MODULE OF THE INTERNATIONAL SPACE STATION. [Photo courtesy NASA.]

How to Become a Ham Radio Operator

THE TDXONE TD-Q8 HT COMPACT HANDHELD TRANSCEIVER KIT INCLUDING LICENSE STUDY GUIDE AND FCC RULE BOOK FROM RADIOCITY, INC., FOR $69.95. [Photo courtesy of TDXone.]

Are you interested in becoming an amateur radio operator? If you live in the US, it's just a matter of taking an examination and obtaining a license from the Federal Communications Commission (FCC). A license is valid for 10 years and is available in three classes: Technician, General, and Extra.

Once you've obtained your entry level Technician Class License, you can upgrade to the higher classes. Although the higher classes offer more communication privileges, the Technician Class License is a great way to sample the field.

In order to obtain your Technician Class License you must pass a 35 question Technician Written Exam. This exam does not require that you understand Morse Code, but you will need to demonstrate a mastery of basic FCC regulations, radio operating practices, and electronics theory.

Once you've received your Technician Class License, you will access privileges to all VHF/UHF amateur bands above 30 MHz, including the two meter band — which is capable of supporting handheld radios. Furthermore, Technician Class hams can operate FM voice, digital packet, television, single-sideband voice, and make international radio contacts via satellites. Additional frequencies are open to Technicians on the 80, 40, and 15 meter bands using continuous wave (CW), and on the 10 meter band using CW, voice, and digital modes.

The cost for basic coursework and license application fee is around $40. The American Radio Relay League is a national association that can assist you with your license, as well as provide you with a vast network of education and support for all of your ham needs.

For more information, visit **www.arrl.org/what-is-ham-radio**.

ELECRAFT K2/100 (K2 + KPA100); K2 HF TRANSCEIVER KIT, $759.95; AND ELECRAFT KPA100 100W OPTION WITH SERIAL INTERFACE KIT, $399.95. [Photo courtesy Elecraft.]

MakerPlot – Part 5
The DIY Software Kit

By John Gavlik and
Martin Hebel

Post comments on this article and find any associated files and/or downloads at **www.nutsvolts.com/index.php?/magazine/article/february2014_MakerPlot.**

An important MakerPlot function is its bi-directional capabilities. What this means is that your micro can control and be controlled by MakerPlot. As we've mentioned before, you should think of MakerPlot as a front panel GUI for your micro because you can create meters, LEDs, and switches that can monitor and control your micro's operation just like a physical front panel can, along with plot areas for your analog and digital data.

In this two-part feature of our series, we're going to introduce you to how MakerPlot accomplishes bi-directional monitoring and control by first adding two physical pushbuttons and an LED, in addition to the 10K pot to our Arduino Uno hardware. Then, we'll go on to show you how to change the setpoint with these two switches, and also how to code the sketch to establish the setpoint and make things happen. After that, we'll show you how MakerPlot can operate with the Arduino for data acquisition and control of the setpoint function.

To get a handle on things, this article begins with uni-directional or one-way control of MakerPlot using an the Uno. So, instead of you clicking buttons and switches on the MakerPlot Interface to change things, we're going to show you how to do it with MakerPlot instructions that are embedded in the Arduino sketch and sent to MakerPlot using the same serial connection that outputs the analog and digital data. (If you haven't already done so, download a free 30 day trial copy of MakerPlot from **www.makerplot.com** to follow along.) Let's get going.

Expanded Arduino Uno Setup

To begin our setpoint example, we've added two physical pushbutton switches and an LED to the Arduino Uno so that we can change the setpoint value for the pot using them (**Figure 1**). Switch SW1 controls incrementing the setpoint and SW2 controls decrementing it. The LED is only there to show you

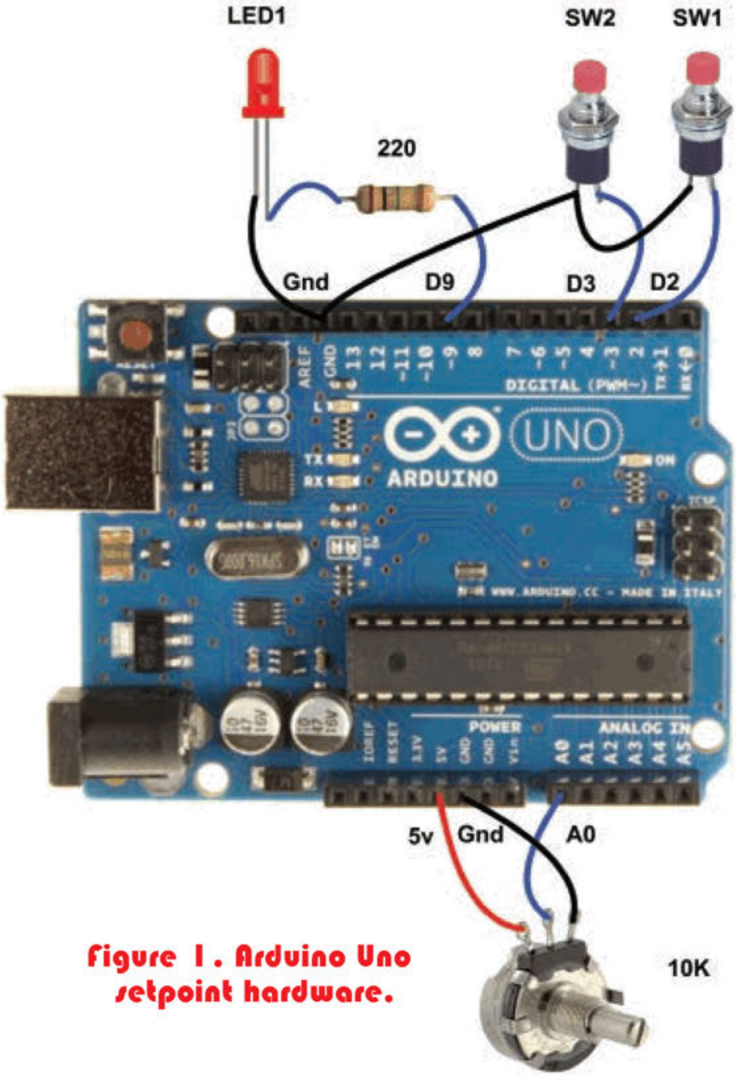


Figure 1. Arduino Uno setpoint hardware.

when the potentiometer analog value goes above or below the setpoint without having to look at the MakerPlot display.

Figure 2 illustrates the data flow from the Arduino into MakerPlot. Right now, it's only in one direction (micro to MakerPlot), but that's just to get things started. Now, let's look at the code.

Setpoint Code

Figure 3 is the sketch that defines how to get the added switch inputs into MakerPlot. You can find this at **www.makerplot.com Arduino Sketch Examples ➔ Arduino Setpoint Example**. Load it onto your Arduino to follow along.

We've added constants to establish where the 10K pot is attached, as well as the new switches and LED on the Uno: SW1 is on pin 2; SW2 is on pin 3; and the LED is on pin 9, with the center tap of the pot attached to analog input A0.

The setup part of the sketch simply enables the internal pull-ups for SW1 and SW2, and defines the LED as an output. The *loop* part of the sketch is equally straightforward. In effect, if SW1 is depressed (logic 0), the setpoint is increased; if SW2 is depressed, it's decreased. Also, if our pot level — the raw 0 to 1023 analog-to-digital (A2D) value — is above the setpoint, the LED on the Uno will illuminate; below it, it will extinguish.

Also, the last part of the *loop* code sends the setpoint and pot information to MakerPlot where the digital setpoint, SW1, and SW2 digital values are plotted on the top (**Figure 4**), along with the analog potentiometer (black) and setpoint (red) levels on the bottom.

Setting up MakerPlot for Remote Control

We're using the same Digital Monitoring Interface as in the previous article as it has LEDs on the right for the digital setpoint SW1 and SW2 switches, as well as two analog bar graphs for both the potentiometer **(Analog 0)** and setpoint **(Analog 1)** values.

To make things clearer (**Figure 5**), we've changed the top three digital LED designations from **Bit 0**, **Bit 1**, and **Bit 2** to **Setpoint**, **SW2 - Decrease**, and **SW1 - Increase** to better reflect the digital setpoint, SW1, and SW2 pushbutton

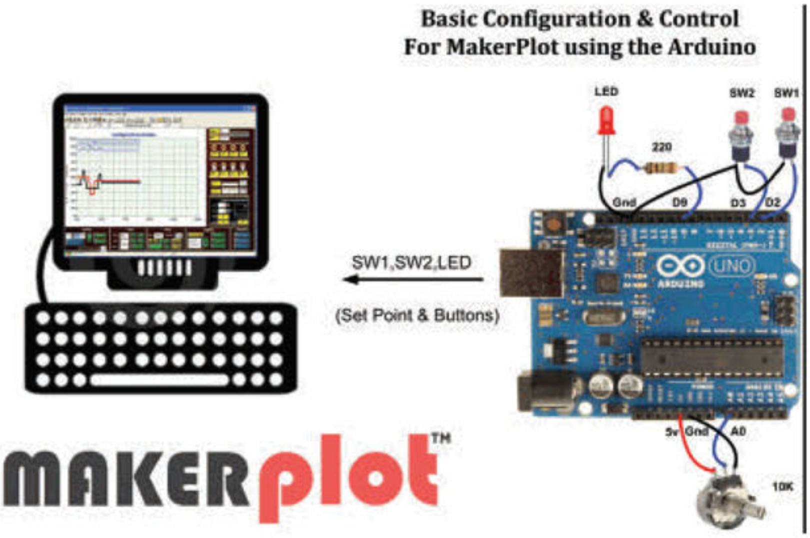


Figure 2. Arduino to MakerPlot data flow.

```
// Arduino Setpoint Example
// This sketch is in the public domain

const int analogInPin = A0;   // Analog input pin that the potentiometer is
const int LEDpin = 9;         // Analog output pin that the LED is attached
const int SW1pin = 2;         // Pushbutton switch, raise setpoint
const int SW2pin = 3;         // Pushbutton switch, lower setpoint

int sensorValue = 0;         // value read from the pot
int setPoint = 100;          // Initial value of setPoint
int SW1state = 0;            // Store state of SW1
int SW2state = 0;            // Store state of SW2
int LEDstate = 0;            // Store state of LED

void setup() {
  // configure hardware
  pinMode(SW1pin, INPUT_PULLUP);  // Enable pull-ups on switches
  pinMode(SW2pin, INPUT_PULLUP);
  pinMode(LEDpin, OUTPUT);        // set LED to be an output pin
  // initialize serial communications at 9600 bps:
  Serial.begin(9600);
}

void loop() {
  // read the analog in value
  sensorValue = analogRead(analogInPin);

  // Check pot value against setpoint, if above light LED
  if (sensorValue > setPoint)
    LEDstate = 1;
  else
    LEDstate = 0;
  digitalWrite(LEDpin,LEDstate);

  // Check states of pushbuttons, if pressed change setpoint up or down
  SW1state = digitalRead(SW1pin);
  if (SW1state == 0)
    setPoint++;
  SW2state = digitalRead(SW2pin);
  if (SW2state == 0)
    setPoint--;

  // print the analog values formatted for MakerPlot
  Serial.print(sensorValue);  // send 1st value
  Serial.print(",");          // send comma delimiter
  Serial.println(setPoint);   // send 2nd value with carriage return

  // print the digital values formatted for MakerPlot
  Serial.print("%");          // send binary indicator
  Serial.print(SW1state);     // send 1/0 for SW1
  Serial.print(SW2state);     // send 1/0 for SW2
  Serial.println(LEDstate);   // send 1/0 for LED with carriage return

  // wait 100 milliseconds before the next loop
  delay(100);
}
```

Figure 3. Arduino setpoint sketch.

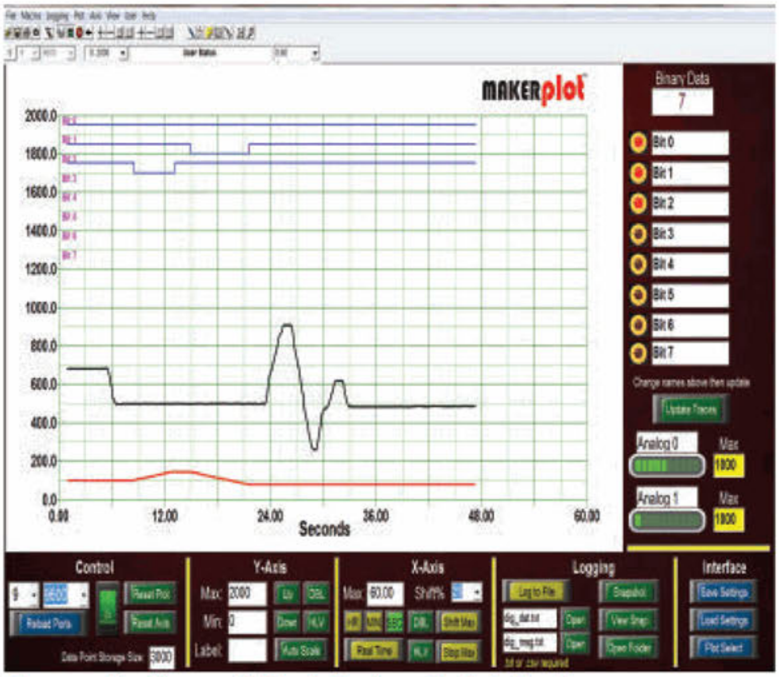


Figure 4. Unmodified MakerPlot Interface.

switches. To do this, just key the new names into the text boxes and click the **Update Traces** button below. We also blanked out the **Bit 3** to **Bit 7** designations since they're not used in this example. **Figure 5** also shows how the two analog bar graphs were renamed to represent the **Pot Value** (top bar graph) and **Setpoint** (bottom bar graph). This is easily done in MakerPlot by simply putting your cursor in the text box and keying in the new name for the control.

MakerPlot as a Front Panel

In this simple setpoint example, we want to demonstrate how MakerPlot can become a GUI front panel for your micro's data and control functions like the two physical switches and LED on the Uno. According to the sketch code, we've established the setpoint at an arbitrary value of 100, so that's what we'll adjust first. This is the line of code that does it:

```
int setPoint = 100;
            // Initial value of setPoint
```

For example, in **Figure 6** when SW1 is pushed, you'll see the digital trace go from high to low (negative logic) and the SW1 LED extinguish. You can also see the analog setpoint (the red line) move up. Going the other way, in **Figure 7** when SW2 is pushed to decrease the setpoint, the digital trace goes from high to low and the SW2 LED extinguishes — again, negative logic — plus the red setpoint trace decreases along with the **Setpoint** bar graph.

When the setpoint is stationary, **Figure 8** illustrates how adjusting the potentiometer value (black trace) back and forth through the setpoint (red trace) causes the digital setpoint line to change from high to low and back again, along with the setpoint LED on the Uno, flashing as the setpoint is crossed. Even though you can't see this, you can imagine what happens. To see a "live" demonstration of this setpoint example, go to **www.makerplot.com** and click on the **Learn Video ➔ Arduino Setpoint Example.** In this short video, everything we've just covered is explained in much greater detail, and you can actually see what takes place.

Controlling MakerPlot From the Micro

We're going to expand the setpoint example a bit. We can keep the same physical Arduino hardware setup with the 10K potentiometer, pushbutton switches, and LED, but we'll need to add a few more lines to our sketch in order to make it add remote control to MakerPlot. For further reference, **Figure 9** illustrates the data flow for our modified sketch.

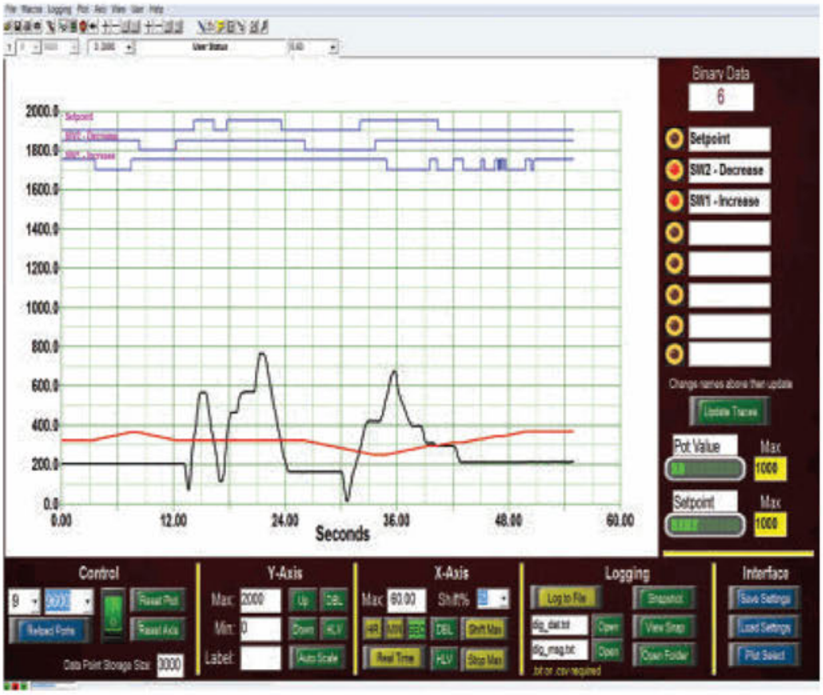


Figure 5. Customized Interface for setpoint example.

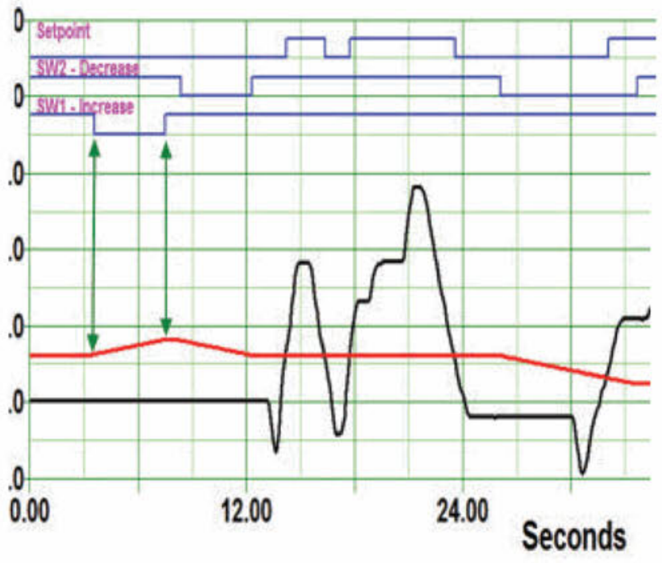


Figure 6. Depress SW1 to increase setpoint.

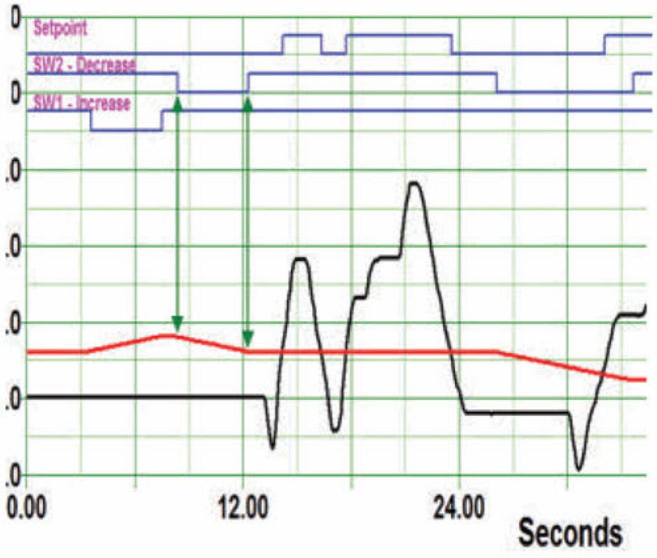


Figure 7. Depress SW2 to decrease setpoint.

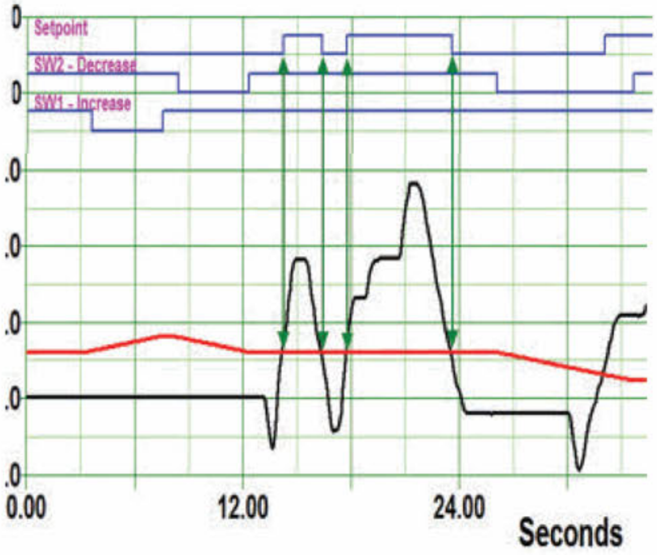


Figure 8. Transitions through setpoint.

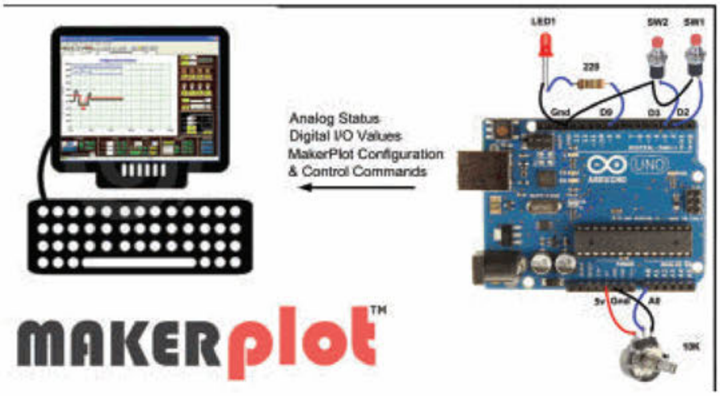


Figure 9. Expanded Arduino to MakerPlot data flow.

In order to establish "hands off" control of the MakerPlot Interface, the micro will send commands (instructions) as well as data to MakerPlot via the same serial link. Up until now, we've shown you how to send only analog and digital data; now, let's make the leap to controlling MakerPlot directly with your micro by also sending instructions to it. **Figure 10** is our modified sketch that does this. You can find it at **www.makerplot.com Arduino Sketch Examples ➔ MakerPlot Arduino Bi-Directional Control – Part 1**. Load it into your Arduino if you're following along.

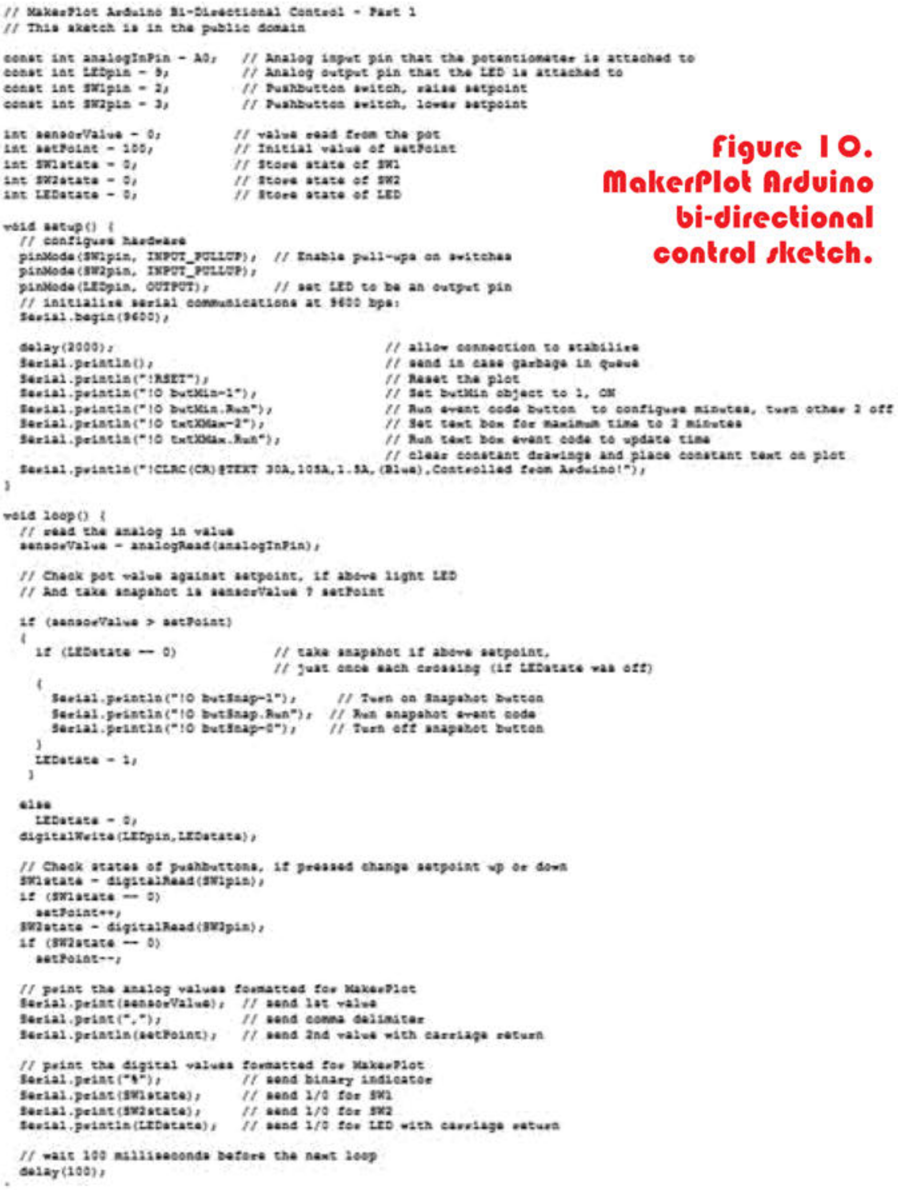
A typical MakerPlot command or instruction starts with an exclamation point (!). Look at the excerpted code in **Figure 11**; the first instruction is a MakerPlot reset instruction (**!RSET**) which clears the Interface of all plots and sets it to the default condition. Like serial data, the reset command is proceeded by the Arduino's **Serial.println** instruction. Then, the instruction is encased in quotes (" ") to make it ASCII, which is then followed by a carriage return. The **Serial.println** instruction handles sending the carriage return.

Another common MakerPlot designator is the capital letter '**O**.' This is an abbreviation of the **POBJ** — or **Plot Object** — MakerPlot command. The next four instructions use the '**!O**' prefix to tell MakerPlot to switch from seconds to minutes on the X-axis (time), and to set the time range to two minutes. The final instruction in this group sends the text "**Controlled from Arduino**" to the Interface.

When the sketch is loaded and run, the result looks like **Figure 12**. We've switched to the **Interactive Interface**, since we're going to use the **Slider** control on the right side for the rest of this example.

What Just Happened?

It's important to understand what just happened in these few lines of code. Look at the bottom menu buttons in **Figure 12** for reference. Rather than manually clicking on the **Reset Plot** button to clear the screen, then clicking on the **MIN** button to switch from seconds to minutes on the time scale) — followed by setting the time duration to two minutes with clicks to the **DBL** or **HLV** buttons — we did all this using these first five serial commands to MakerPlot from the Arduino (**Figure 11**).



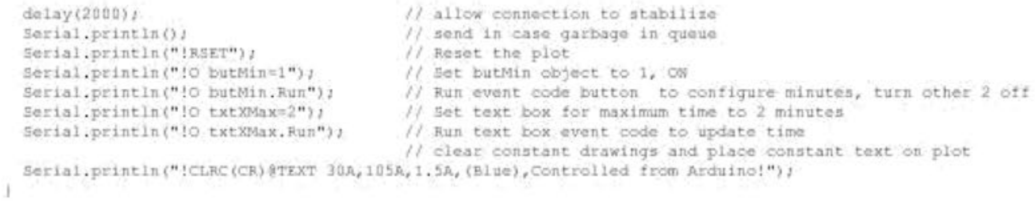
```
// MakerPlot Arduino Bi-Directional Control - Part 1
// This sketch is in the public domain

const int analogInPin = A0;   // Analog input pin that the potentiometer is attached to
const int LEDpin = 9;         // Analog output pin that the LED is attached to
const int SW1pin = 2;         // Pushbutton switch, raise setpoint
const int SW2pin = 3;         // Pushbutton switch, lower setpoint

int sensorValue = 0;         // value read from the pot
int setPoint = 100;          // Initial value of setPoint
int SW1state = 0;            // Store state of SW1
int SW2state = 0;            // Store state of SW2
int LEDstate = 0;            // Store state of LED

void setup() {
  // configure hardware
  pinMode(SW1pin, INPUT_PULLUP);  // Enable pull-ups on switches
  pinMode(SW2pin, INPUT_PULLUP);
  pinMode(LEDpin, OUTPUT);        // set LED to be an output pin
  // initialize serial communications at 9600 bps:
  Serial.begin(9600);

  delay(2000);                            // allow connection to stabilize
  Serial.println();                       // send in case garbage in queue
  Serial.println("!RSET");                // Reset the plot
  Serial.println("!O butMin=1");          // Set butMin object to 1, ON
  Serial.println("!O butMin.Run");        // Run event code button  to configure minutes, turn other 2 off
  Serial.println("!O txtXMax=2");         // Set text box for maximum time to 2 minutes
  Serial.println("!O txtXMax.Run");       // Run text box event code to update time
                                          // clear constant drawings and place constant text on plot
  Serial.println("!CLRC(CR)@TEXT 30A,105A,1.5A,(Blue),Controlled from Arduino!");
}

void loop() {
  // read the analog in value
  sensorValue = analogRead(analogInPin);

  // Check pot value against setpoint, if above light LED
  // And take snapshot is sensorValue ? setPoint

  if (sensorValue > setPoint)
  {
    if (LEDstate == 0)             // take snapshot if above setpoint,
                                   // just once each crossing (if LEDstate was off)
    {
      Serial.println("!O butSnap=1");     // Turn on Snapshot button
      Serial.println("!O butSnap.Run");  // Run snapshot event code
      Serial.println("!O butSnap=0");    // Turn off snapshot button
    }
    LEDstate = 1;
   }

  else
    LEDstate = 0;
  digitalWrite(LEDpin,LEDstate);

  // Check states of pushbuttons, if pressed change setpoint up or down
  SW1state = digitalRead(SW1pin);
  if (SW1state == 0)
    setPoint++;
  SW2state = digitalRead(SW2pin);
  if (SW2state == 0)
    setPoint--;

  // print the analog values formatted for MakerPlot
  Serial.print(sensorValue);  // send 1st value
  Serial.print(",");          // send comma delimiter
  Serial.println(setPoint);   // send 2nd value with carriage return

  // print the digital values formatted for MakerPlot
  Serial.print("%");          // send binary indicator
  Serial.print(SW1state);     // send 1/0 for SW1
  Serial.print(SW2state);     // send 1/0 for SW2
  Serial.println(LEDstate);   // send 1/0 for LED with carriage return

  // wait 100 milliseconds before the next loop
  delay(100);
```

Figure 10. MakerPlot Arduino bi-directional control sketch.

Okay ... now let's look at what else our remote control sketch does. In the first part of the loop (**Figure 13**), it reads the potentiometer value then goes on to test it against the current setpoint. If the potentiometer value exceeds the setpoint, the code instructs MakerPlot to "snap an image" of the Interface screen. This is handled with these three lines of code:

```
Serial.println("!O butSnap=1");
  // Turn on Snapshot button
Serial.println("!O butSnap.Run");
  // Run snapshot event code
Serial.println("!O butSnap=0");
  // Turn off snapshot button
```

Notice the '**!O**' prefixes that precede the **butSnap** instructions. This three-line sequence is equivalent to manually clicking on the **Snapshot** button in the menu section. The result is an image of when the potentiometer value crossed the setpoint line, and **Figure 14** shows it. To view it, click the **View Snap** button in the **Logging** menu. The jpg image looks just like the "live" Interface, so it's easy to confuse it from the real thing. You can use these jpg images as a visual record of your experiments or process control activities. If you're a student (or teacher), these same images can be incorporated into lab reports.



```
  delay(2000);                            // allow connection to stabilize
  Serial.println();                       // send in case garbage in queue
  Serial.println("!RSET");                // Reset the plot
  Serial.println("!O butMin=1");          // Set butMin object to 1, ON
  Serial.println("!O butMin.Run");        // Run event code button  to configure minutes, turn other 2 off
  Serial.println("!O txtXMax=2");         // Set text box for maximum time to 2 minutes
  Serial.println("!O txtXMax.Run");       // Run text box event code to update time
                                          // clear constant drawings and place constant text on plot
  Serial.println("!CLRC(CR)@TEXT 30A,105A,1.5A,(Blue),Controlled from Arduino!");
}
```

Figure 11. MakerPlot Instruction Examples.

Winding Up for Now

The reset of the loop code (**Figure 10**, again) simply outputs the setpoint, SW1, SW2, and potentiometer data values to MakerPlot. What we want to do next is add more code to the sketch so that we can use the **Slider** control on the **Interactive Interface** to adjust the analog setpoint value. This will be the beginning of real bi-directional control (MakerPlot ➔ micro). We'll do that in the next article. In the meantime, you can view the video of this article at **www.makerplot.com Learn ➔ Arduino Setpoint Example with GUI Control.** The video will give you a better idea of how everything works.

Conclusion

In this first of a two-part feature on bi-directional data acquisition and control, we showed you how your code can affect one-way control of MakerPlot by outputting commands from the microcontroller instead of clicking on buttons and switches on the Interface screen.

We also introduced you to some basic MakerPlot instructions. These are the same instructions that are used to create the controls (buttons, switches, meters, etc.) on the Interface screen. What's interesting to note is that these same instructions can come directly from your micro, so

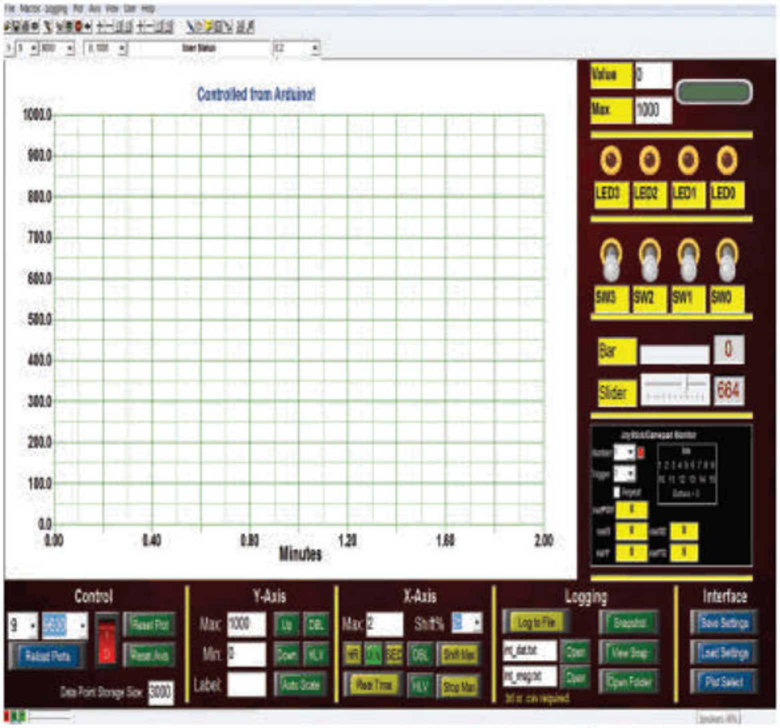


Figure 12. Interactive Interface for setpoint example.

```
void loop() {
  // read the analog in value
  sensorValue = analogRead(analogInPin);

  // Check pot value against setpoint, if above light LED
  // And take snapshot is sensorValue ? setPoint

  if (sensorValue > setPoint)
  {
    if (LEDstate == 0)             // take snapshot if above setpoint,
                                   // just once each crossing (if LEDstate was off)
    {
      Serial.println("!O butSnap=1");      // Turn on Snapshot button
      Serial.println("!O butSnap.Run");   // Run snapshot event code
      Serial.println("!O butSnap=0");     // Turn off snapshot button
    }
    LEDstate = 1;
  }
```

Figure 13. MakerPlot snapshot instructions.

it's entirely possible to completely build an Interface directly from your micro. We'll get into that in a subsequent article.

In the meantime, remember that MakerPlot is available as a free download. If you like what you see and what it does, you can order it from the *NV* Webstore at a discounted price.

That's all for now, so just remember: ***Got Data – MakerPlot It!*** **NV**

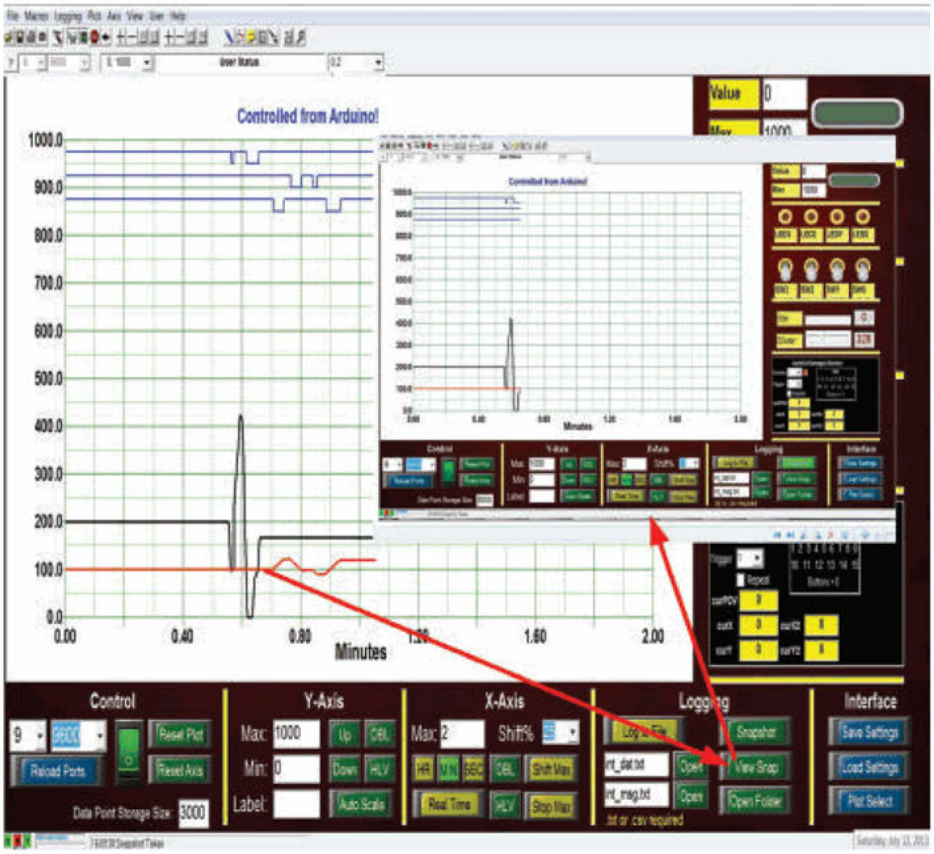


Figure 14. Snapshot jpg image of setpoint crossing.

Reader Feedback

Continued from page 7

available to the transistor. Using that current and the beta of the transistor, you can then calculate the resistance required: Rb = (Vin - VBEsat)/(ICmax /Beta). Lower values of Rb will also work but cause a higher Ib than what is required.

Larry Cicchinelli K3PTO

You are, of course, right on the money. Not sure how this one passed through the cracks, but it did.

Thanks for the eagle eyes.

Bryan Bergeron
Editor

To Zip or Unzip

On page 81 of the January 2014 issue, Margaret Lyell talks about .ZIP and .GZ files, and all of the steps to move them to a Raspberry Pi. Has everyone forgotten that these many steps are not necessary?

Why not Unzip the files first on your PC or MAC, and then use WinSCP to move them over to the RPi? Simple!

Ted Mieske

Thanks, Ted. Great feedback on the feedback!

Bryan Bergeron

A Closer Look

Regarding the January 2014 Developing Perspectives editorial, electronic magnifiers have their uses, but the Luxor magnifiers are wonderful when you're drilling PCBs. I have a stand-mounted Dremel tool with carbide bits chucked into a collet. My chair is low enough that the drill press table is at eye level. The Luxor lamp is swung into position between the work and my face, providing three important functions: excellent lighting, good magnification, and — most importantly — eye protection from debris and breaking drill bits. The setup makes PCB drilling most comfortable, even over long time periods. In addition, I have a small muffin fan at the side of the work to blow most of the debris off to the side.

Dean Huster

Thanks for taking the time to write. I have a Luxor on my desk, as well. The halogen bulb makes a great heat shrink tubing heat source when I just have one piece to work with and don't want to pull out the big heat gun. I've been saved from solder splatter on several occasions by the large lens. Glad you've made use of your investment, as well.

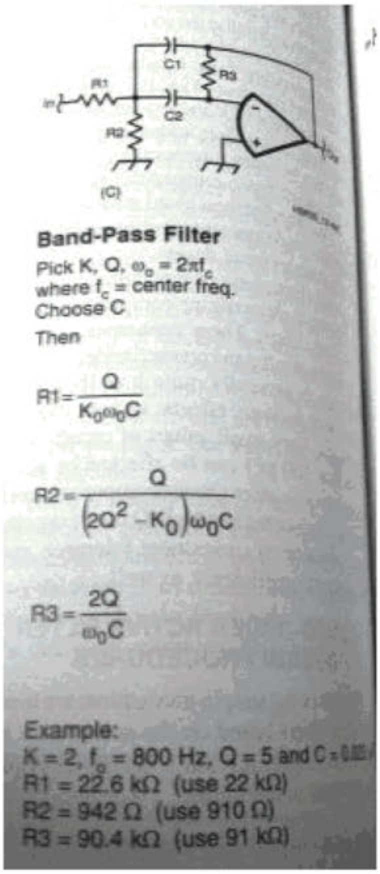
Bryan Bergeron

Passing Compliment

Regarding the question in the December 2013 Q&A: Nice job with the KCL exercise with the band pass filter. Brought back ancient memories!

Figure 1 is similar info from the 2013 *ARRL Handbook*, page 11.22, Figure 11.46.

James Lynes



Band-Pass Filter

Pick K, Q, $\omega_o = 2\pi f_c$
where f_c = center freq.
Choose C
Then

$$R1 = \frac{Q}{K_0 \omega_0 C}$$

$$R2 = \frac{Q}{\left(2Q^2 - K_0\right)\omega_0 C}$$

$$R3 = \frac{2Q}{\omega_0 C}$$

Example:
K = 2, f_o = 800 Hz, Q = 5 and C = 0.0
R1 = 22.6 kΩ (use 22 kΩ)
R2 = 942 Ω (use 910 Ω)
R3 = 90.4 kΩ (use 91 kΩ)

PLASTIC PARTS CAN BE MADE ECONOMICALLY FOR LIMITED QUANTITY APPLICATIONS

Clickfold Plastics utilizes a process that takes flat 1/8th inch plastic sheet and fabricates it into useful parts and enclosures. Since there is no hard tooling involved, the unique thermo-folding operation allows for fast, highly repeatable distortion-free part forming using 3D driven high speed CNC routers.

Franklin Huggins needed a limited supply of plastic parts as accessories for radio controlled model racing boats. An airfoil was developed to increase the speed and stability for the model boats. Injection molding the part required expensive tooling, was not timely, and uneconomical for the low volume of units initally required. So, Franklin came to Clickfold Plastics in Charlotte, NC for samples to test.

Within a week, prototypes were produced for testing on the boats. Boat speeds increased by 10% with improved stability. Two phases of prototypes were made to obtain improved performance, and within one month the new parts were on the market to model racing boat parts distributors.

Franklin Huggins credits Clickfold Plastics for its fast delivery of prototypes, quickly developing several designs of the product without expensive tooling. The CNC programming and first part production cost less than $1,000.

Check out **www.clickfold plastics.com** for details on ordering custom plastic parts for your special projects.

DSL and Cable TV Broadband Internet Access: How Do they Work?

Chances are you use one of these technologies. Most individuals get their high speed broadband Internet access via a digital subscriber line (DSL) or a cable TV company modem. While some direct fiber and wireless broadband systems are deployed, the DSL and cable TV connections dominate in over 80% of homes and businesses. Both of these systems have been around for over a decade, but recent upgrades have made them faster. This article shows the technical details of each system while highlighting the most recent new features and specifications.

DIGITAL SUBSCRIBER LINE

DSL broadband systems use the existing public switched telephone network (PSTN) wiring. Also known as the plain old telephone system (POTS), this vast network throughout the world uses unshielded twisted pair (UTP) cabling as the transmission medium. This network was designed to carry voice signals in the 300 to 3,400 Hz range, and few ever imagined that it would eventually carry high speed digital data. Yet today, it is possible to transmit digital data at rates up to about 50 Mbps under the right conditions. New standards push for up to 1 Gbps data rates.

UTP is a great medium for voice. It is simple, low cost, rugged, and very flexible. The typical length of a connection from the telephone central office to a home or office phone is in the 9,000 to 18,000 foot range. Therefore, this connection suffers from very high attenuation and it is vulnerable to noise pickup from many sources. Despite this limitation, electronic technology has overcome these problems. Attenuation factors of up to 90 dB on an 18,000 foot line really reduce signal strength, but special amplifiers and frequency compensation methods successfully mitigate this problem. This has made DSL the most widely used high speed Internet connection worldwide.

Early developments in dial-up modems demonstrated that this medium could carry digital data. Using FSK and PSK techniques, modems were developed to carry data at rates from 1200 to 9600 b/s. Using quadrature amplitude modulation (QAM) – a mix of phase and amplitude modulation with a center frequency in the 1,700 Hz range – modems were created that were capable of delivering data at a rate to about 53 kb/s. Such modems were very popular for a while until DSL was created.

Several variants of DSL were developed over the years, but the most popular and widely implemented is called asymmetrical DSL or ADSL. The asymmetrical designation refers to the fact that the download and upload speeds are different. Download from source to consumer is much faster than the upload speed from consumer to destination. There are multiple versions of ADSL and an even faster version called very high speed DSL (VDSL) that is used for carrying video.

The basic structure of ADSL uses a form of orthogonal frequency division multiplexing (OFDM) called discrete multitone (DMT). Using QAM, DMT transmits data divided amongst many 4.3125 kHz wide subcarriers. These subcarriers called bins or channels are distributed along the cable bandwidth as shown in **Figure 1**. *(NOTE: The diagram is not to scale.)* The 0 to 4 kHz spectrum is reserved for analog voice calls. The spectrum from 28.875 kHz to 138.8 kHz is reserved for 25 bins used in upstream transmission. The spectrum from 138.8 kHz to 1.104 MHz holds 256 bins for downstream transmission.

Depending on the type of modulation in each bin, line length, and noise conditions, a data rate up to 60 kb/s per bin is possible. The typical maximum realistic data rate for a 9,000 foot line is 6.144 Mb/s downstream and 576 kb/s upstream. For a maximum 18,000 foot line, the typical maximum rate is 1.536 Mb/s downstream and 384 kb/s upstream. Keep in mind that the rates vary considerably with line length and line conditions.

Download from source to consumer is much faster than the upload speed from consumer to destination.

DMT works by dividing the high speed serial data up into many slower streams that are transmitted in parallel or concurrently, one stream per subcarrier. Using QAM, the rate can be as high as 60 kbps per bin. The key to DMT operation and practicality is the use of DSP to implement the modulation scheme using the fast Fourier transform (FFT) for reception and the inverse FFT for transmission. These mathematical operations are implemented in software on a digital signal processor (DSP), or in a field programmable gate array (FPGA), or other system on a chip (SoC). An FFT takes a digitized analog signal and breaks it down into the individual frequency components present. This is used in the receiver. An inverse FFT assembles the binary words into a sequence that will generate a modulated signal.

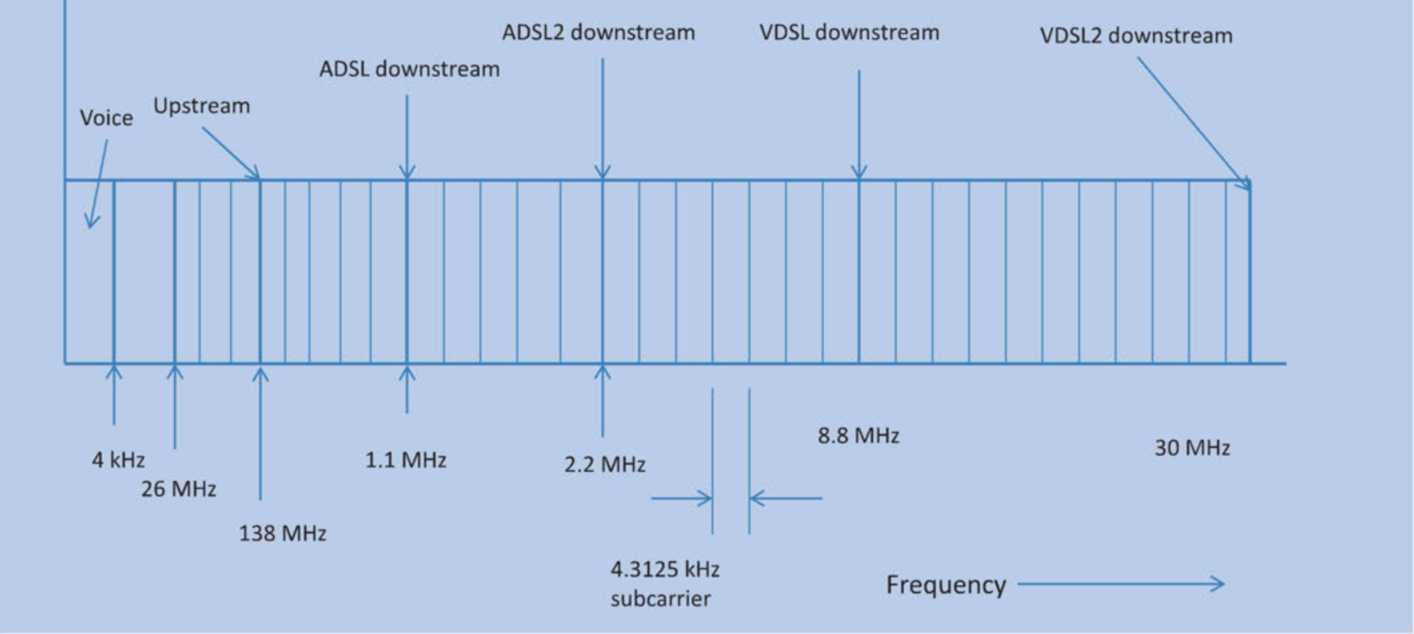
While the initial version of ADSL is capable of a maximum of 8 Mbps downstream and 1.3 Mbps upstream, other versions have been developed to improve on that. A newer version called ADSL2 extends the bandwidth on the UTP cable to 2.2 MHz (**Figure 1**). This enables a maximum data rate of 12 Mbps downstream and 1.3 Mbps upstream. An even newer version has extended this to 24 Mbps downstream and 3.3 Mbps upstream. Again, keep in mind that the cable length is the limiting factor.

To keep cable lengths short, the telephone carriers have installed an interface unit called a digital subscriber line access multiplexer (DSLAM) in neighborhoods where the UTP from subscriber lines terminate. This helps ensure that lines will not run more than about 5,000 feet. The DSLAMs connect back to the central office with fiber optic cable.

As mentioned previously, the even newer very high speed version of DSL called VDSL was developed to carry digital video. It extends the frequency range on the cable to 8.8 MHz. This allows up to 2,048 bins producing data rates to 50 Mbps. Extending the bandwidth to 12, 17, or 30 MHz and increasing the number of bins further boosts data rates to 100 Mbps or more. To get these speeds, cable lengths are limited to the 1,000 to 3,000 foot range. Careful placement of local DSLAMs permits this.

A newer version called VDSL2 further boosts data rates. Using up to 30 MHz bandwidth on the cable and doubling the bin size to 8.625 kHz for higher level modulation methods, data rates can be up to 200 Mbps. The technology that makes this possible is known as vectoring. Vectoring is a technique for overcoming the crosstalk problem on the cable. Most telephone cabling bundles multiple UTP lines together. The close capacitive and inductive coupling causes signals on one cable to introduce interference on adjacent lines. In other words, each line

■ FIGURE 2. This is the DSL frequency spectrum on a single UTP cable showing the bandwidth used for the various versions of DSL. (Not to scale.)



interferes with the others. The induced signals are small and are generally not a problem at low data rates as long as the lines are kept short. To achieve the higher data rates, the crosstalk is the limiting factor. Vectoring is an advanced signal processing method that helps cancel crosstalk.

You may have encountered VDSL or VDSL2 if you have used AT&T's U-verse system. It was developed to carry multiple TV channels to compete with local cable TV companies. It also provides Internet connection data rates to 50 Mbps.

That's not all, however. A new and forthcoming version of DSL is known as G.fast. Like the other versions of DSL, it is a standard of the International Telecommunications Union (ITU). It is designed to achieve up to 1 Gbps over copper twisted pair. It does this by extending the bandwidth on the cable to 106 MHz or 212 MHz. Then – using improved methods of vectoring and a technique called channel bonding – the 1 Gbps level can be achieved. Channel bonding is the use of two or more UTP lines in parallel. The main limitation is the range which is restricted to 250 meters.

G.fast has not been implemented yet, but could be popular as it can deliver data speeds normally associated with fiber optic cable but at a fraction of the cost. It could be used to distribute video and Internet access in multi-tenant buildings or as backhaul for various wireless services.

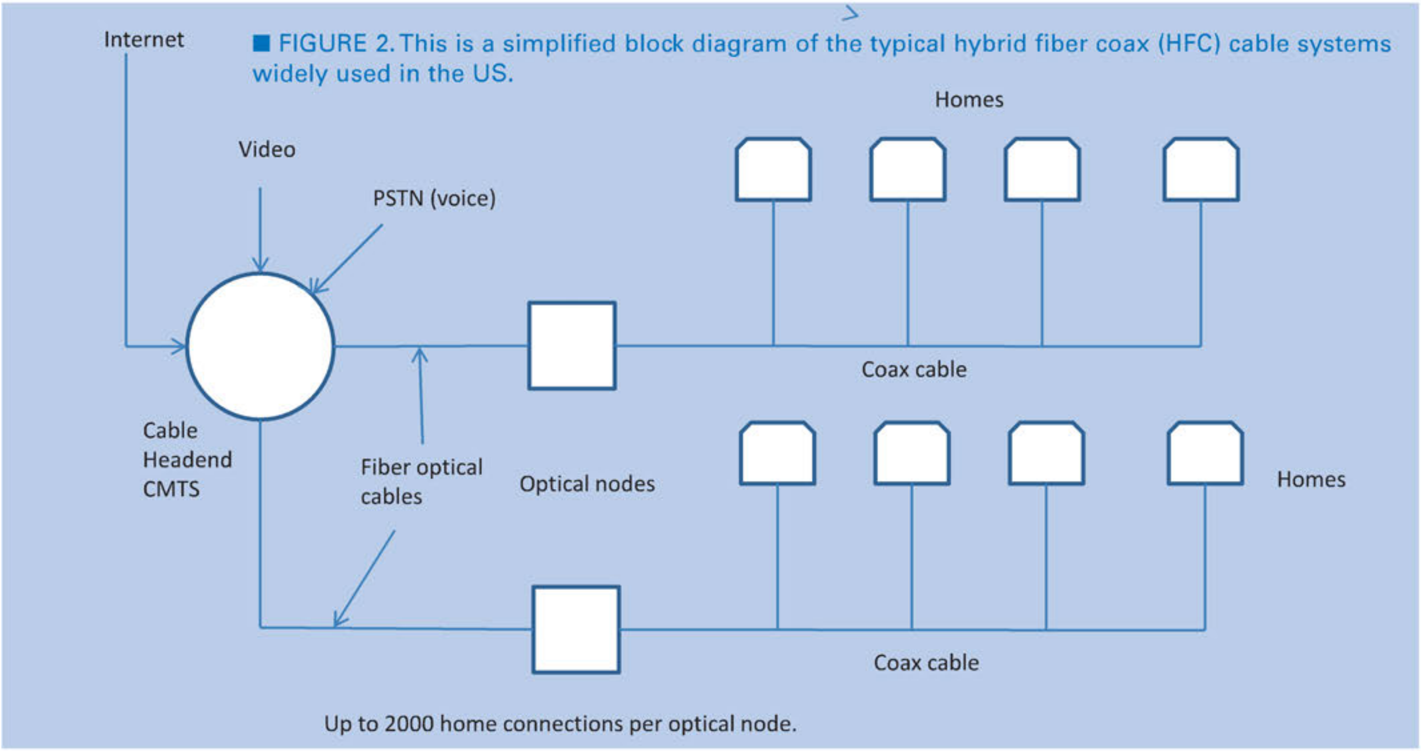
CABLE TV INTERNET

Cable TV that is about 60+ years old was originally developed to deliver analog TV. Today, it delivers digital TV, voice over Internet Protocol (VoIP) digital phone service, and Internet access. Over 50% of US households have cable TV Internet service.

Local cable systems vary considerably but all are of the same basic design using a combination of fiber optic cable and coax cable known as a hybrid fiber coax (HFC) system. The basic idea is illustrated in **Figure 2**. The cable headend – also known as the Cable Modem Termination System (CMTS) – is where the system connects to the various video sources by satellite, fiber, or antenna. It also provides a connection to the Internet core network and the PSTN for voice. It then distributes the video and other services via a fiber optic cable to connection nodes located in the neighborhoods where services are to be distributed. The nodes provide optical to coax and coax to fiber conversions, as well as amplification. The signals are then sent to the homes by way of coax cable, usually RG-6/U. Typically, an optical node can handle up to about 2,000 homes. In the home, the coax connects to a cable modem for Internet access and VoIP service, or a cable TV set top box.

Most HFC systems organize the video and data by channels. These 6 MHz wide channels are distributed from 50 MHz to about 700 MHz. There used to be one analog TV station per 6 MHz channel. Today – thanks to digital compression techniques – two or three digital video signals can occupy one 6 MHz wide channel. The coax cable bandwidth used is commonly at least 750 MHz, or in some systems up to

■ FIGURE 2. This is a simplified block diagram of the typical hybrid fiber coax (HFC) cable systems widely used in the US.



860 MHz or 1 GHz. Many channels can be accommodated. Most of the spectrum is for downstream delivery of video or Internet downloads. However, the spectrum from about 5 MHz to 40 MHz or 65 MHz in some systems is used for upstream communications from the users.

HFC cable systems use a set of standards developed by CableLabs. Known as the Data Over Cable Service Interface Specification (DOCSIS), this standard defines the spectrum assignments, modulation types, error correction, security, and other protocol related specifications. The current version is DOCSIS 3.0. Downstream modulation is either 64QAM or 256QAM, providing a data rate up to 38 Mbps. Higher rates can be achieved by channel bonding – the use of two or more channels to transmit data in each channel concurrently. Upstream modulation is typically QPSK, but some systems allow faster 16QAM or up to 128QAM.

CableLabs recently announced DOCSIS 3.1 – a major upgrade to provide even higher data rates. The 3.1 version uses orthogonal frequency division multiplexing (OFDM) and an improved error correction method called low density parity check (LDPC). The OFDM format eliminates the 6 MHz channels and replaces them with channels that can be from 24MHz to 192 MHz wide using OFDM subcarriers that are in the 20 kHz to 50 kHz range. Using modulation from 256QAM to 4096QAM, data speeds can easily reach the peak of 10 Gbps downstream and 1 Gbps upstream. That is certainly fast enough to compete with fiber to the home (FTTH), fiber optical systems from Verizon (FiOS), Google, or others.

DOCSIS 3.1 has not been implemented yet. It will take time for cable companies to make the necessary hardware and software changes. Look for these faster systems in 2015 and beyond. **NV**

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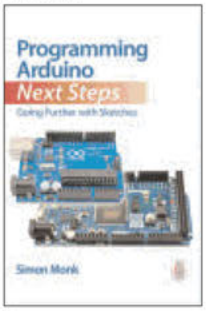
Programming Arduino Next Steps: Going Further with Sketches
by Simon Monk



Arduino guru Simon Monk reveals advanced programming techniques for Arduino! *Programming Arduino Next Steps: Going Further with Sketches* is the must-have follow-up to Monk's bestseller, *Programming Arduino: Getting Started with Sketches.* Aimed at experienced programmers and hobbyists who have mastered the basics, this book takes you "under the hood" of the Arduino, revealing professional-level programming secrets.

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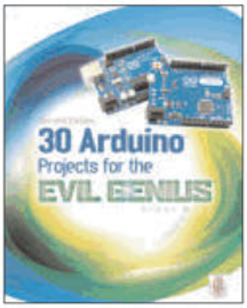
30 Arduino Projects for the Evil Genius: Second Edition
by Simon Monk



Fully updated throughout, this do-it-yourself guide shows you how to program and build fascinating projects with the Arduino Uno and Leonardo boards, and the Arduino 1.0 development environment. *30 Arduino Projects for the Evil Genius, Second Edition*, gets you started right away with the simplified C programming you need to know, and demonstrates how to take advantage of the latest Arduino capabilities.

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by Ronald Quan

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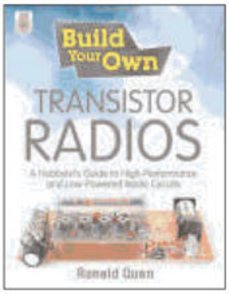

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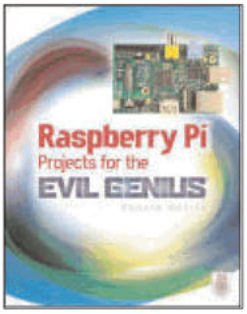
by Donald Norris



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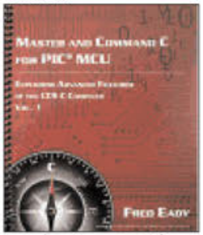
by Fred Eady



Master and Command C for PIC MCU, Volume 1 aims to help readers get the most out of the Custom Computer Services C compiler for PIC microcontrollers. The author describes some basic compiler operations that will help programmers particularly those new to the craft create solid code that lends itself to easy debugging and testing. As Eady notes in his preface, a single built-in CCS compiler call (output_bit) can serve as a basic aid to let programmers know about the "health" of their PIC code.

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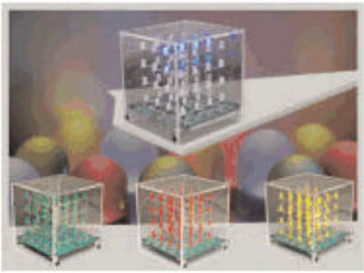

This kit shows you how to build a really cool 3D cube with a 4 x 4 x 4 monochromatic LED matrix which has a total of 64 LEDs. The preprogrammed microcontroller that includes 29 patterns that will automatically play with a runtime of approximately 6-1/2 minutes.
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As seen in the March 2013 issue.

This kit is a great project for high school and university students. The unit detects and displays levels of radiation, and can detect and display dosage levels as low as one micro-roentgen/hr. The LND712 tube in our kit is capable of measuring alpha, beta, and gamma particles.

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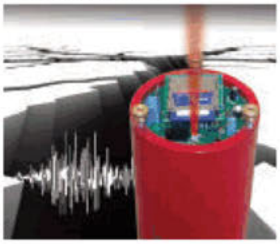

As seen in the May 2012 issue.

Now you can record your own shaking, rattling, and rolling.

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As seen in the November 2011 issue.

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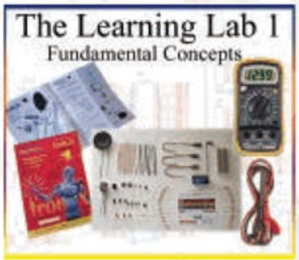

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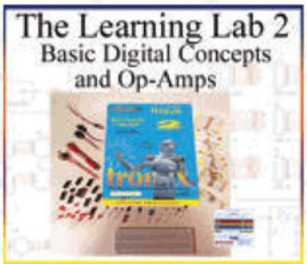

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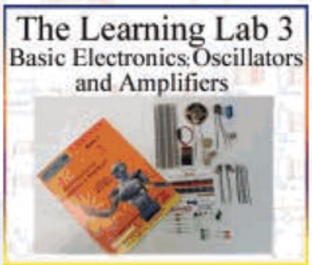

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ELECTRONET

BY JOE PARDUE

C PROGRAMMING - HARDWARE - PROJECTS

The Arduino Classroom
Arduino 101 — Chapter 2: Digital Output - LEDs

This article continues the Arduino 101 series started last month as part of a formal curriculum where you can learn computing and electronics basics much like you would if you took a standard semester-based introductory course. To help in this, I've started www.arduinoclassroom.com where each of these magazine articles will be presented along with laboratories, exercises, quizzes, and a forum. Now instead of being a passive reader, you get a chance to have some interaction and to talk back. You can find the Arduino 101 Projects Kit — a kit of components for the projects in this course — from the *Nuts & Volts* Webstore.

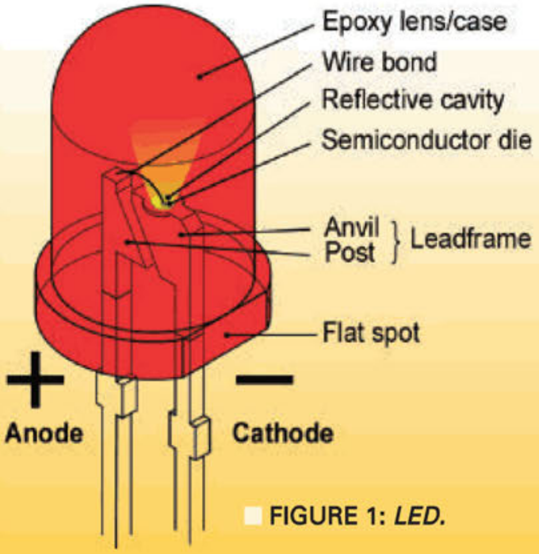

FIGURE 1: *LED.*

LEDs are Everywhere

LEDs (Light Emitting Diodes) have been used as indicator lights for decades in things like alarm clocks and entertainment systems, but recently they have started taking over many general lighting tasks since they are durable and very energy efficient. This month, you will learn how to design circuits using LEDs and how to use LEDs with Arduino software to indicate events to people using your system.

Figure 2 shows the four

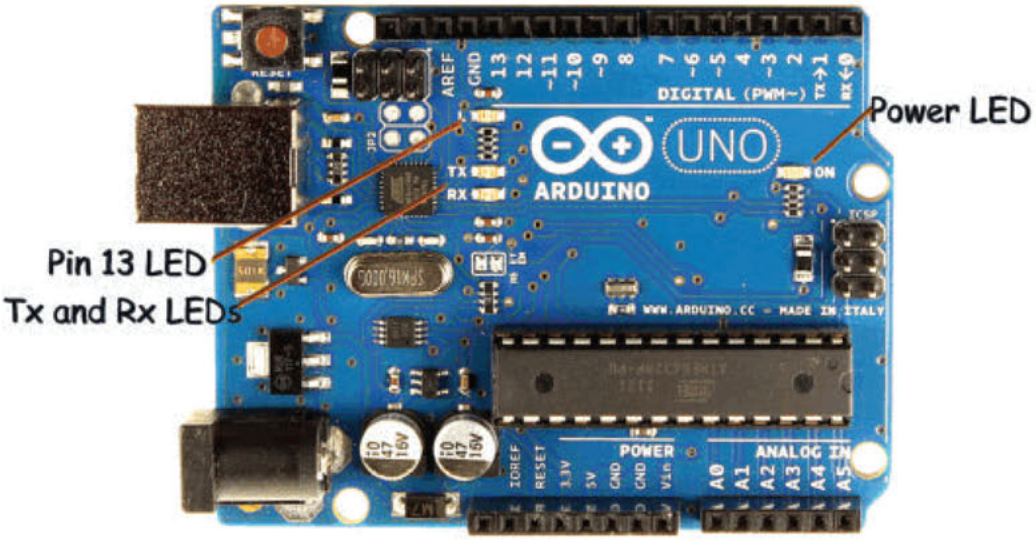

FIGURE 2: *Arduino Uno R3 LEDs.*

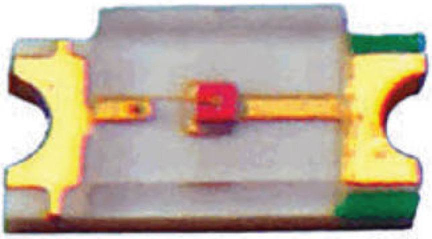

FIGURE 3: *SMD LED.*

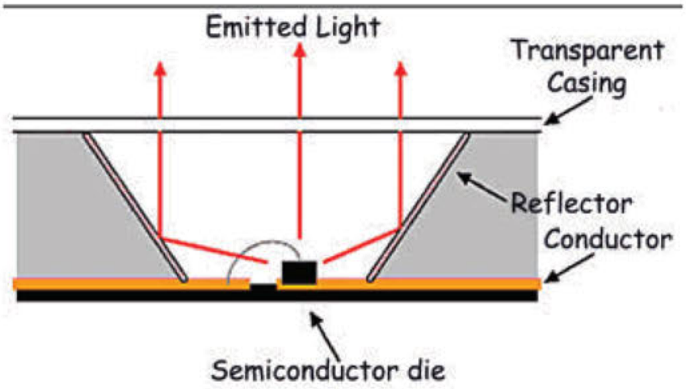

FIGURE 4: *LED cross section.*

LEDs on the Arduino. The power LED indicates that the board has power (this LED is the first and most fundamental debugging indication — if something seems amiss, first make sure the power LED is on). The TX and RX LEDs indicate serial communications traffic with the TX and RX LEDs blinking when transmitting and receiving, respectively. This provides another very useful diagnostic tool which helps you see if the board is communicating and in which direction the communication is going. The pin 13 LED is connected to the Arduino digital I/O pin 13 and can be used for a variety of software tests without having to add any external hardware to see the software in action — our first program in Chapter 1 blinked this LED to indicate that the program was working.

The LEDs on the Arduino are SMD (Surface-Mount Devices) like the one shown in **Figure 3**. While they do not look like the LED in **Figure 1**, the difference is in the size of the packaging. The active circuit — the silicon die — is about the same size in both packages. The limits to how small the LED is made is not the size of the semiconductor die, but the surrounding casing and connections which must be large enough to be handled by people and machinery.

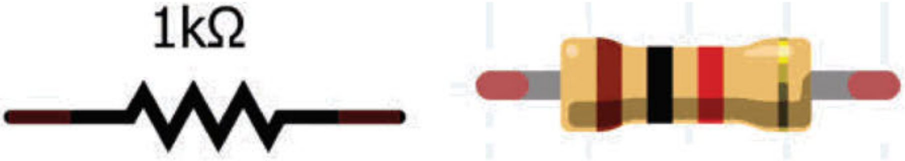

FIGURE 5: *Resistor schematic symbol and Fritzing illustration.*

How an LED Works

The name says it all: light emitting diode. A diode is an electronic device that only allows current to flow in one direction. It acts as a sort of valve that prevents the current from backing up or flowing the wrong way. [We will learn more about diodes in a later chapter.] A diode can be made from semiconductors — the same silicon-based material that computer chips are made from. Some of these materials configured as diodes emit light when a current passes through them. The color of the light depends on the materials used. The brightness of an LED is proportional to the electricity flowing through it. However, if you provide too much electricity, the LED heats up and burns out.

Since too much electrical current will cause an LED to burn out, we need a way to control the flow of electricity to provide the maximum light without risking destroying the LED. Electrical flow is known as **current**. We use a component called a **resistor** that *resists* current flow to an acceptable level. Resistors have a given resistance value measured in units called **ohms** which you may also see expressed with the Greek character omega: Ω. To control the current through our LED in this lab, we will use a resistor with a value of 1,000Ω.

What is a Resistor?

Materials with low resistance are known as conductors, while materials with high resistance are known as insulators. Electrons move easily in some things such as copper wire, but are stopped cold by things such as glass. Copper has very low resistance. The jumper wires in the Projects Kit have near zero ohms resistance (about one ohm per 62 feet), while glass can have millions of ohms of resistance.

Electronic components often have symbols associated with them that are used in **schematics** which are drawings of an electronic circuit. **Figure 5** shows a schematic symbol for resistors next to a Fritzing drawing of a resistor showing the color stripes. [Fritzing is an open source electronic design program for drawing breadboards, schematics, and printed circuit boards (PCBs).]

The ohm value of resistors is shown by the color of the stripes around the resistor; refer to **Figure 6**. Notice

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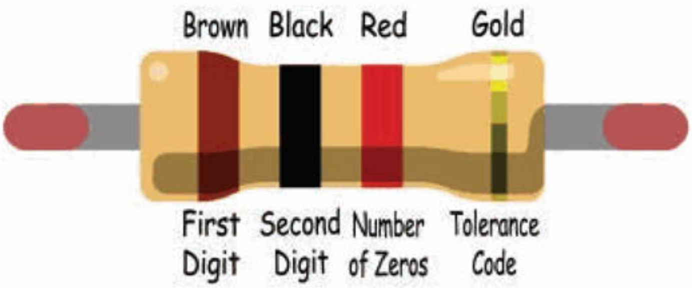
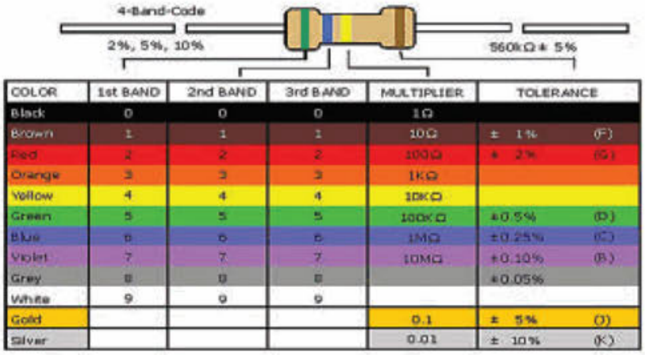


■ **FIGURE 6:** ***Resistor value stripes.***


4-Band-Code
2%, 5%, 10%
560kΩ ± 5%

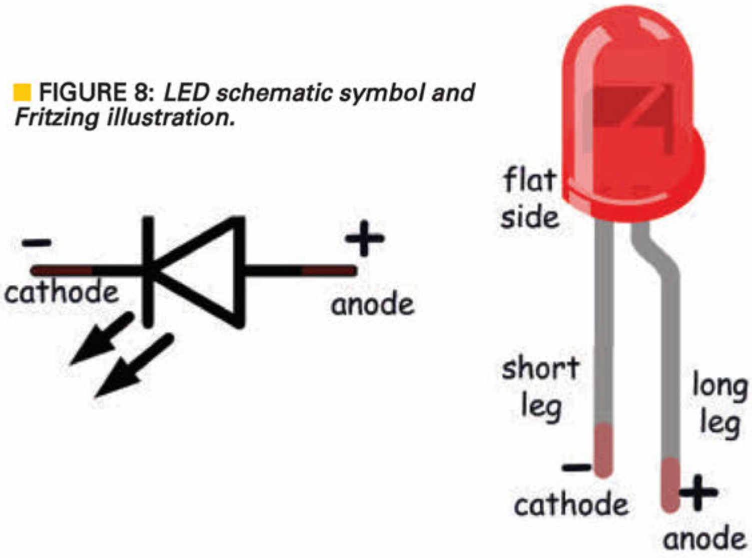
COLOR	1st BAND	2nd BAND	3rd BAND	MULTIPLIER	TOLERANCE
Black	0	0	0	1Ω	
Brown	1	1	1	10Ω	± 1% (F)
Red	2	2	2	100Ω	± 2% (G)
Orange	3	3	3	1KΩ	
Yellow	4	4	4	10KΩ	
Green	5	5	5	100KΩ	±0.5% (D)
Blue	6	6	6	1MΩ	±0.25% (C)
Violet	7	7	7	10MΩ	±0.10% (B)
Grey	8	8	8		±0.05%
White	9	9	9		
Gold				0.1	± 5% (J)
Silver				0.01	± 10% (K)

■ **FIGURE 7:** ***Resistor values card.***

that the stripes are bunched toward one end; this is the end you start counting from.

By referring to a resistor values card (like the one in **Figure 7**), we see that the first band is brown and represents a one; the second band is black for zero; the third band is red for two zeros. So, we read this as a 1,000Ω resistor. The fourth band is gold for ±5% tolerance. This means the the actual resistance is 1,000 plus or minus 5% of 1,000, which is 50Ω. So, we have a tolerance from 950Ω to 1,050Ω which is good enough for our purposes.

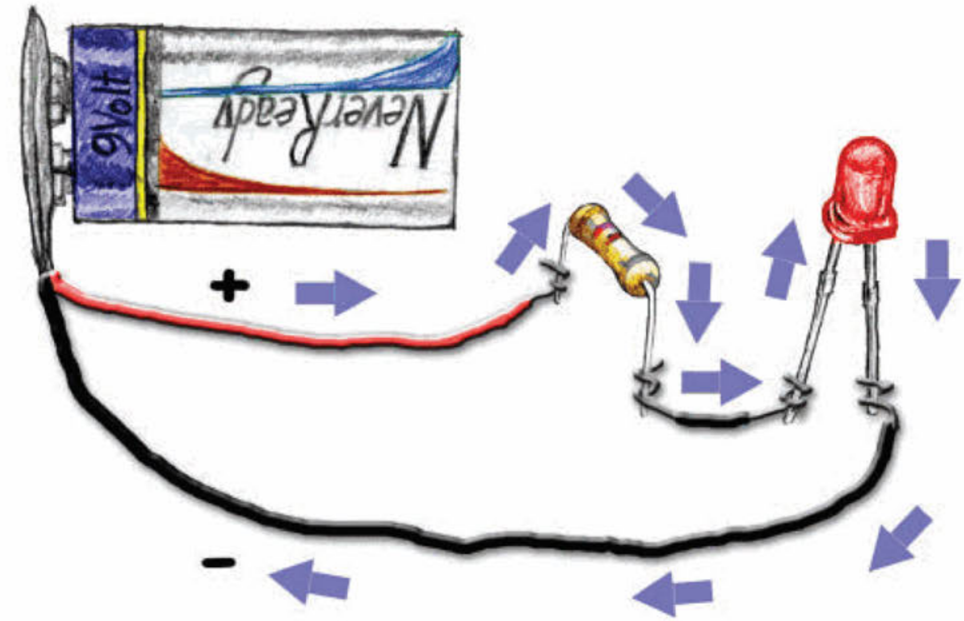
■ **FIGURE 8:** ***LED schematic symbol and Fritzing illustration.***



The LED Component

In **Figure 8**, we see the schematic symbol and Fritzing illustration for an LED.

The schematic symbol has a triangle and a bar that shows the direction that the diode allows current to flow; the two arrows indicate that this particular diode emits light. Because this component is directional with respect to current, there is a positive side in which the current enters and a negative side in which the current exits. The positive side is called the anode and is sometimes represented with a + (plus sign). The negative side is called a cathode and is represented by - (negative sign).



■ **FIGURE 9:** ***Electric current from battery through resistor and LED.***

Building the Circuit

What is a Circuit?

We get electricity to do useful work by channeling it from devices that produce electric force (like generators and batteries) through devices that do electric work (like lights and motors), then back to the device that created the force. That last part is critical. Circuit is just a fancy way of saying 'circle.' Electricity must complete a circle to do useful work.

Figure 9 shows arrows marking the direction of conventional current from the higher voltage side of a nine volt battery (the positive terminal) through a resistor and an LED, then back around to the lower voltage terminal of the battery.

You have probably seen really complex circuits on PCBs or as schematics, but no matter how complex it looks it can be simplified to one part producing the force as a current, one part using that force to do work, and the electrical connection between them.

Wonder why we have to add 'conventional' to current? Well, that's because Benjamin Franklin himself guessed wrong when he said that charge is carried by positive particles that flow from the + side of a circuit to the - side. It was much later that folks came to realize that the actual charge carrier is an electron — which has a negative charge. Of course by then, text books all had current going from + to -, so we are stuck with this backwards concept.

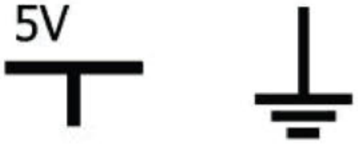


FIGURE 10: ***Schematic symbols for five volts and ground.***

FIGURE 11: ***ATmega328 DIP package.***

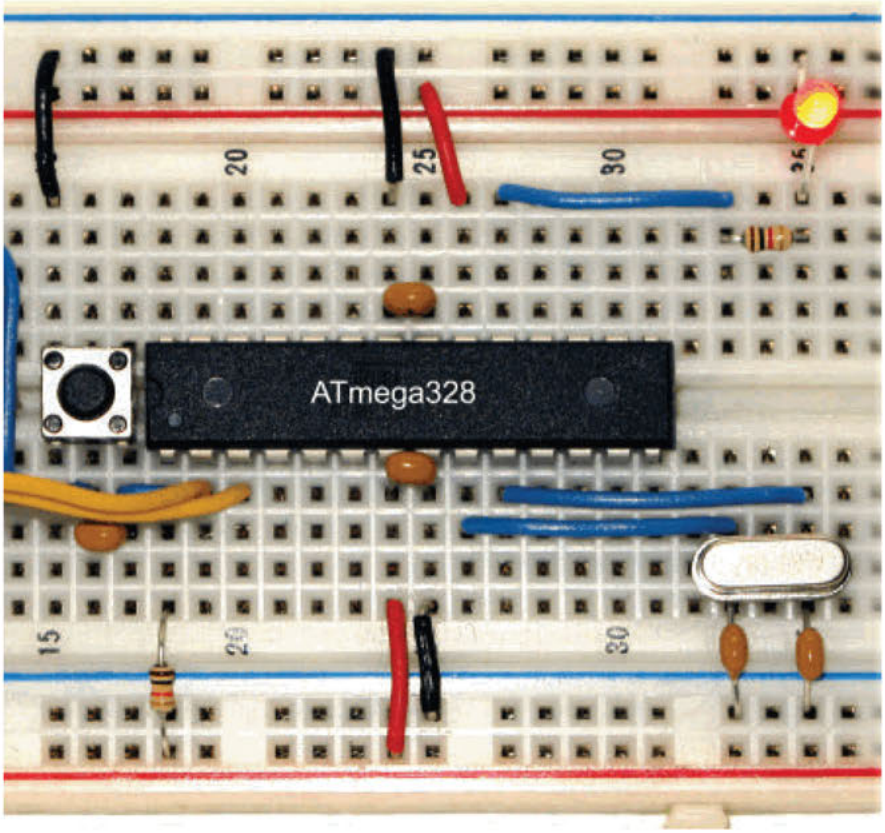


FIGURE 12: ***ATmega328 on a breadboard.***

Schematic Symbols for 5V and GND

Current flows from the higher voltage [anode (+)] to the lower voltage. In **Figure 10**, we see the schematic symbols for the current source and destination. The source shown [anode (+)] is five volts and the destination is zero volts [cathode (-)] — also known as ground (GND).

We will build our circuits on a Arduino mini breadboard shield (included in the Arduino 101 Projects Kit). First, let's see how a breadboard works.

How a Breadboard Works

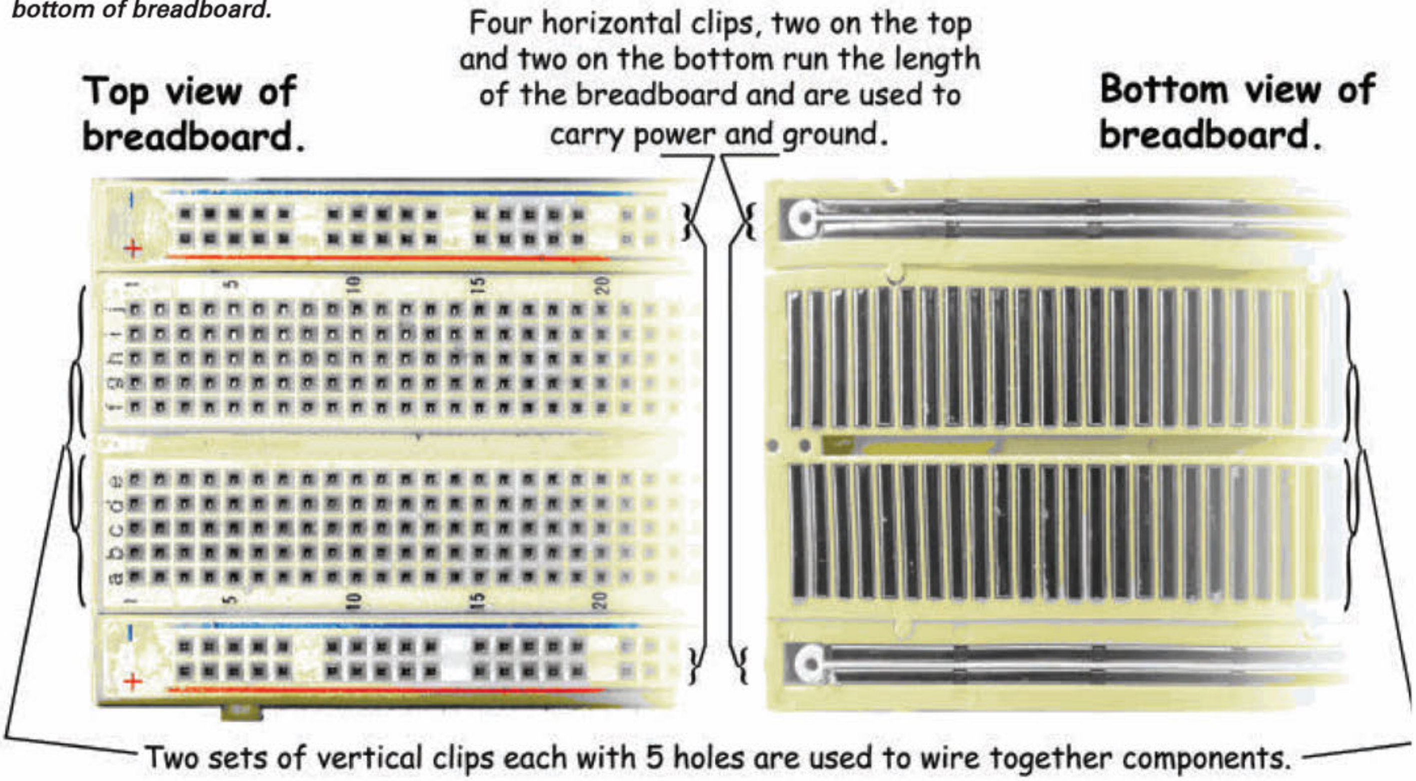
In the good old days, electronics experimenters would build prototypes by nailing components to an actual wooden breadboard and then soldering wire between connection points. Today's solderless breadboards are made of plastic blocks with holes on 0.1 inch centers that allow you to insert jumper wires into hidden clips below the holes.

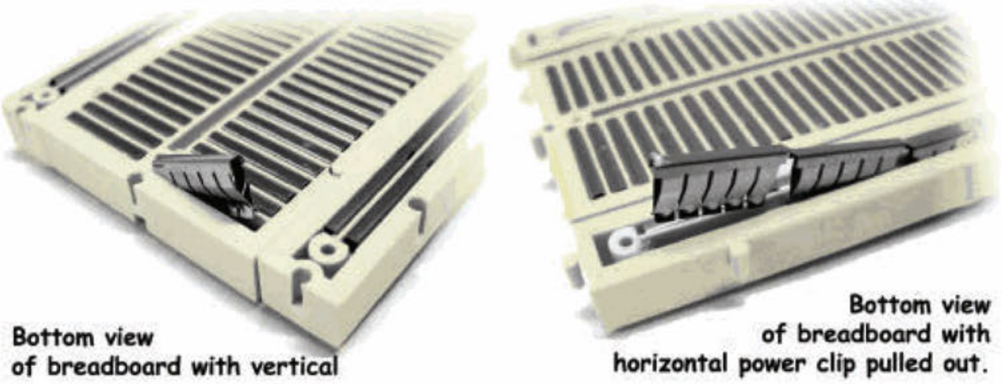
Integrated circuits (ICs) are made of tiny blocks of silicon that are much too small and delicate to be used by hand. Early on, they were encapsulated in a special package like the one shown in **Figure 11**. This DIP (Dual Inline Package) packaging has the IC silicon encapsulated in a block of epoxy with the pins directed downward. These pins are usually lined up 0.1 inches apart on the side of the package, with the two lines often 0.3 inches apart.

Breadboards were designed to facilitate prototyping with these packages so that these DIP ICs could be plugged into the breadboard with the pins lined up on either side of the trough in the middle of the breadboard (shown in **Figure 12**). The vertical rows of sockets shown above and below the IC are electrically connected and allow components to be added to the prototype to make temporary circuit contacts.

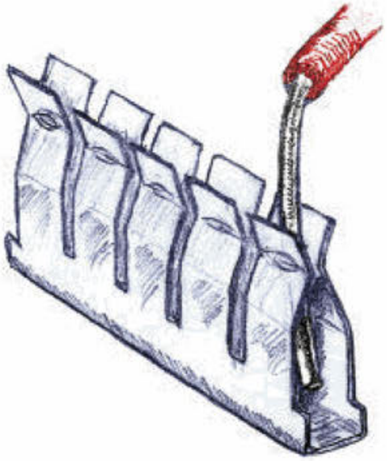
Figure 13 shows the top and bottom of a solderless

■ FIGURE 13: *Top and bottom of breadboard.*


Top view of breadboard.
Four horizontal clips, two on the top and two on the bottom run the length of the breadboard and are used to carry power and ground.
Bottom view of breadboard.
–
+
a b c d e f g h i j
1 5 10 15 20
Two sets of vertical clips each with 5 holes are used to wire together components.


Bottom view of breadboard with vertical
Bottom view of breadboard with horizontal power clip pulled out.

■ FIGURE 14: *Breadboard bottom with clips pulled out.*

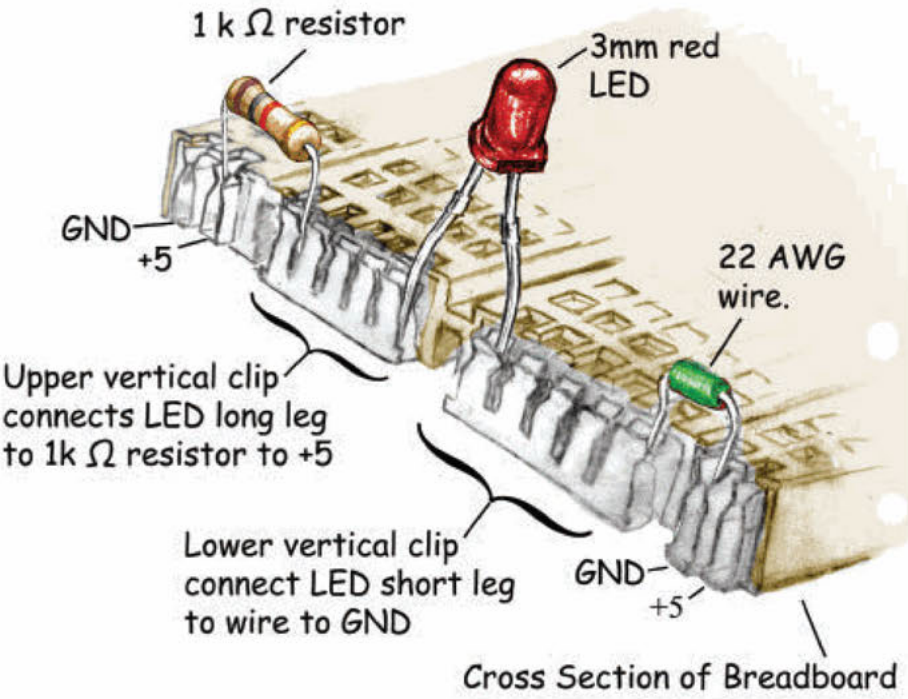


■ FIGURE 15: *Illustration of how clip connects to wire.*

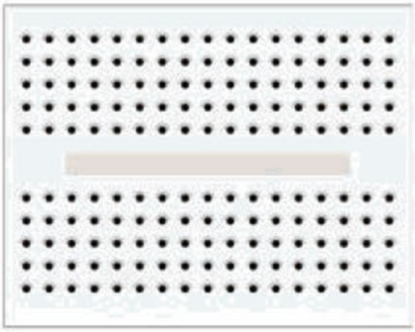
breadboard (the bottom has the foam tape stripped off to show the connections). **Figure 14** shows the clips pulled out. **Figure 15** shows how a clip grabs a wire, and **Figure 16** shows a cutaway drawing with an LED, 1K Ω resistor, and a jumper wire all connected such that if you have +5 volts in the upper + channel and GND in the lower – channel, the LED should light up.

Our Mini Breadboard

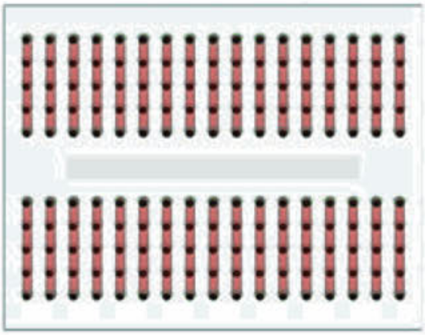
A miniature breadboard shown in **Figure 17**. **Figure 18** shows that this board has 17 columns of sockets with two sets of five connected sockets — one each above and below the central trough. This provides 170 tie-points for connecting circuits together.


1 k Ω resistor
3mm red LED
GND
+5
22 AWG wire.
Upper vertical clip connects LED long leg to 1k Ω resistor to +5
Lower vertical clip connect LED short leg to wire to GND
GND
+5
Cross Section of Breadboard

■ **FIGURE 16:** ***Cross section with components.***



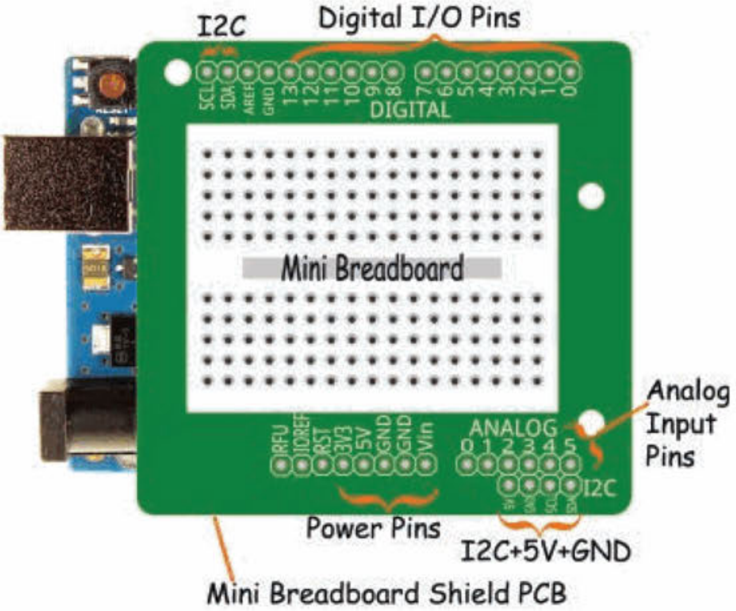
■ **FIGURE 17:** ***Mini breadboard.***



■ **FIGURE 18:** ***Mini breadboard internal connections.***

The Mini Breadboard Shield Mounted on an Arduino

Our electronics and computing learning platform throughout this series has a mini breadboard shield mounted on an Arduino as shown in **Figure 19**. This platform provides many useful and convenient features that you will learn about in upcoming lab exercises.


I2C
Digital I/O Pins
SCL SDA AREF GND 13 12 11 10 9 8 7 6 5 4 3 2 1 0
DIGITAL
Mini Breadboard
RFU IOREF RST 3V3 5V GND GND Vin
ANALOG 0 1 2 3 4 5
I2C
Analog Input Pins
Power Pins
I2C+5V+GND
Mini Breadboard Shield PCB

■ **FIGURE 19:** ***Prototyping area.***

Lab 1: Assemble Your Arduino Mini Breadboard Shield.

Required tools:

1 Arduino
1 Proto shield

Estimated time for this lab: Five minutes

BE VERY CAREFUL NOT TO BEND THE PROTO SHIELD LEGS WHEN YOU DO THIS LAB!

Check off when complete:

❑ Place the shield with the long legs above the mating Arduino header sockets as shown in **Figure 20**.

❑ Place the legs **carefully** into the sockets, making sure they align properly as shown in **Figure 21**. You may have to use your fingernails to carefully align the pins while gently applying pressure.

❑ **Figure 22** shows the legs pushed in all the way. Note there is about 1/16" space between the bottom of the shield and the top of the Arduino sockets.

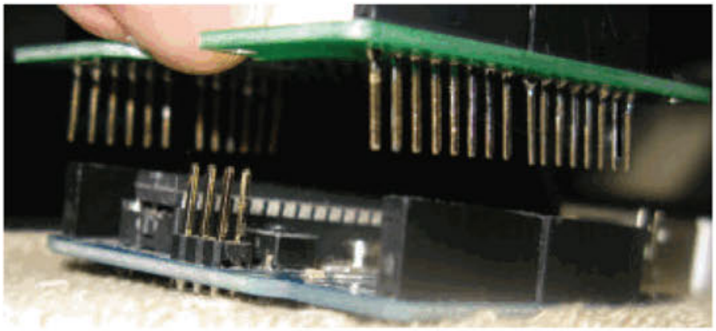


FIGURE 20: *Plug shield into Arduino, Step 1.*

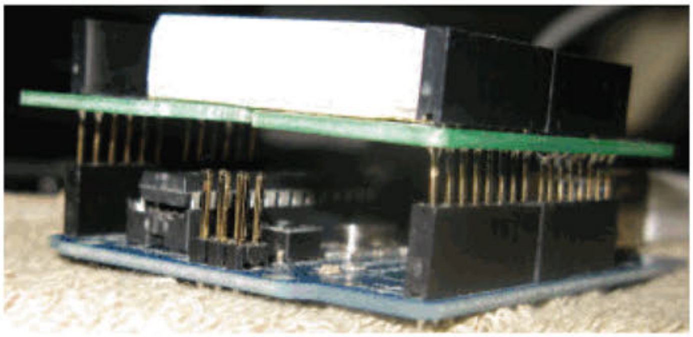


FIGURE 21: *Plug shield into Arduino, Step 2.*

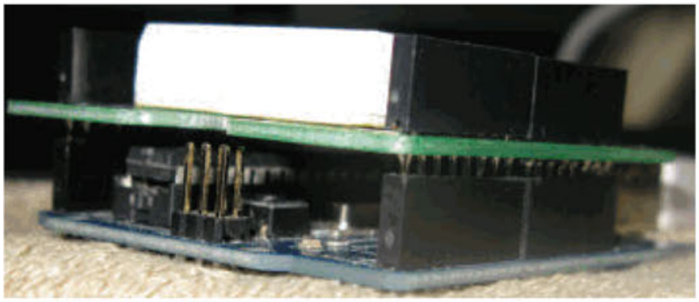


FIGURE 22: *Plug shield into Arduino, Step 3.*

Lab 2: Lab 2: How to Use an LED – Analog.

Required tools:

1 Arduino
1 Proto shield

Estimated time for this lab: 20 minutes

Parts Required:

1 Red LED
1 1,000Ω resistor
2 Jumper wires

Check off when complete:

❑ CAUTION: MAKE SURE POWER IS OFF BEFORE YOU BUILD A CIRCUIT! Check that the Arduino USB is unplugged and that you do not have a battery plugged into the power connector.

❑ Plug your mini breadboard shield into your Arduino as described in Lab 1.

❑ Plug an LED into the breadboard as shown in **Figure 23**. Make sure that the long leg is towards the bottom of the board as shown. Notice that the illustration shows the short leg connected to the column of five sockets above the LED and that the long leg connects to the column of five sockets below the LED.

❑ Plug a 1,000Ω resistor (brown, black, red bands) as shown in **Figure 24** and note the connection to the five sockets in the two columns – one unconnected and the other connected to the long leg of the LED.

❑ Attach a wire between the column of five sockets on the LED short leg to **GND** (ground), and then connect the column of five sockets on the resistor to **5V** (five volts) as shown in **Figure 25**.

❑ Provide power to your system by either plugging the Arduino USB into a PC (**Figure 26**) or plugging a nine volt battery into the power jack (**Figure 27**). When you provide power, the LED should light up.

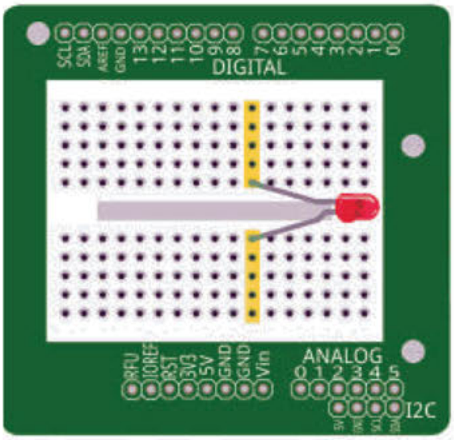


FIGURE 23: *LED in mini breadboard.*

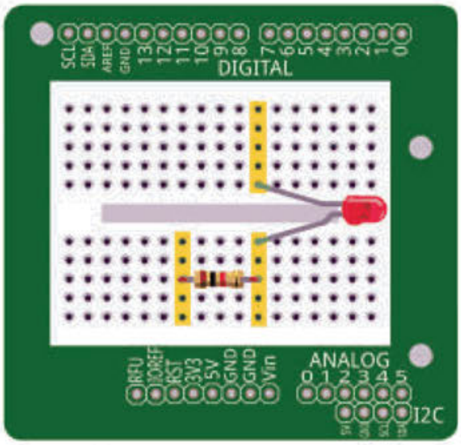
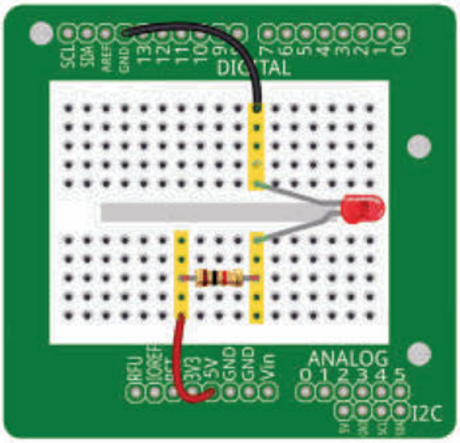


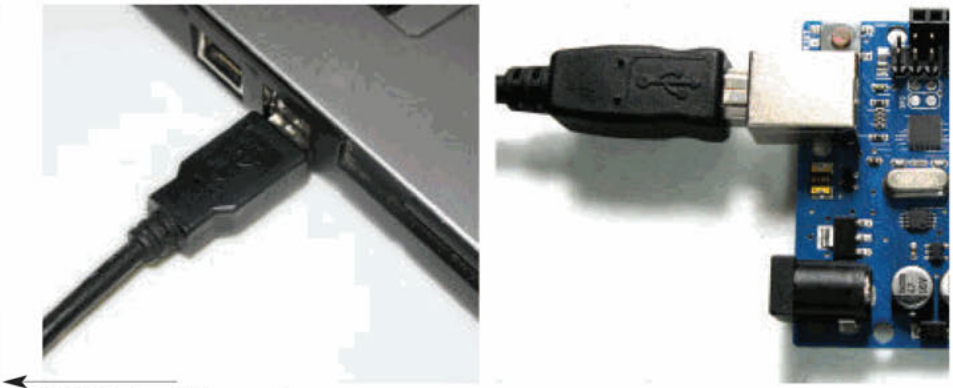
FIGURE 24: *LED + resistor circuit.*

In **Figure 28**, you see a schematic on the left of the LED circuit on the right. At the top, you see a symbol with 5V above it. That symbol is for the input of five volts into the circuit. At the bottom, you can see three progressively smaller bars that are the schematic symbol for ground, which is zero volts. Since current flows from a higher voltage to a lower voltage, here it will run from 5V to 0V (ground), and the LED will light up.

Notice that the current in the schematic image flows from the top to the bottom, but in the proto shield



■ **FIGURE 25:** ***LED + resistor + power + ground circuit.***



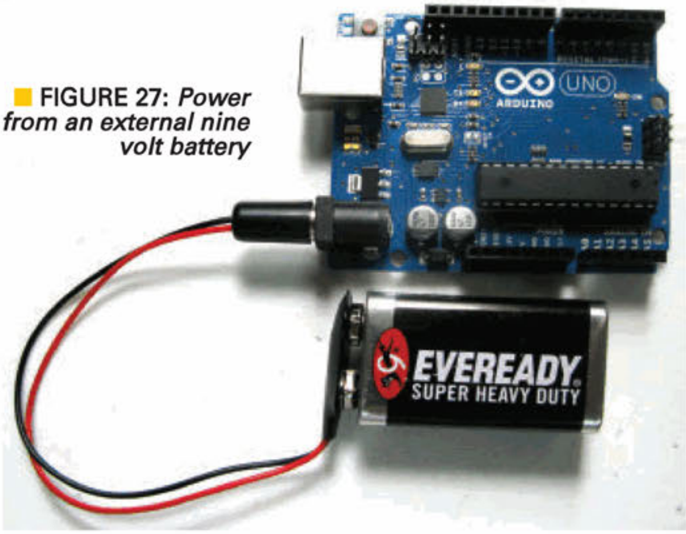
■ **FIGURE 26:** ***Power from the PC.***

illustration the current flows from the bottom to the top. These two images are 'upside down' relative to each other. This is just an artifact due to the traditional way schematics are drawn — usually with the higher voltage toward the top and the lower voltage or ground toward the bottom. The 'flipped' illustration is due to the 5V being at the 'bottom' of the image on the proto shield. This may be momentarily confusing, but it is good to keep in mind that current flows from high to low voltage and has nothing to do with the physical orientation of the device.

What Happens if We Reverse the Current?

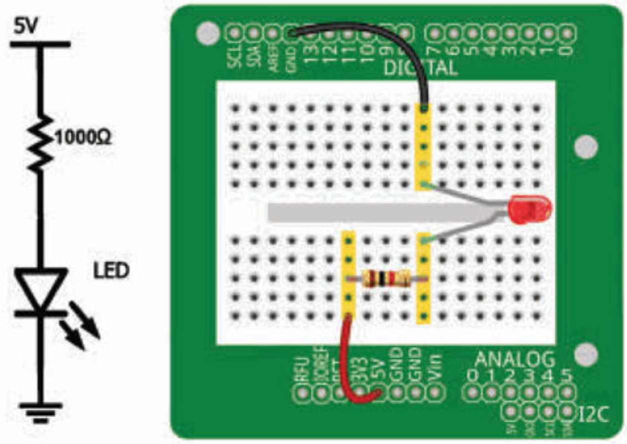
In **Figure 28**, we have the five volts connected such that the current runs from the five volts through the resistor and the LED to ground. What happens if we reverse the connection and place the five volts at the bottom and the ground at the top of the schematic as shown in **Figure 29**?

❏ Reverse the 5V and GND wires as shown in **Figure 29**. What happens?

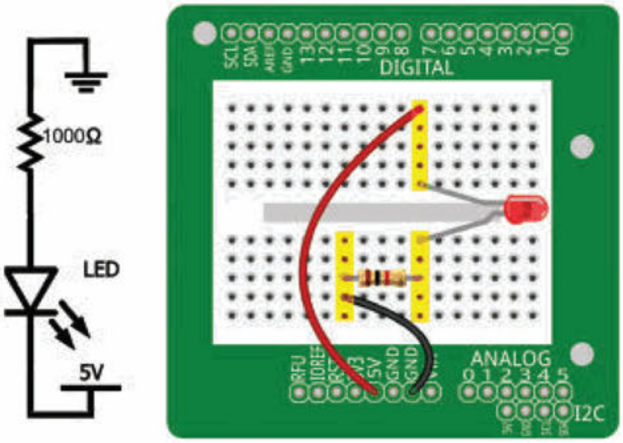


■ **FIGURE 27:** ***Power from an external nine volt battery***

Why didn't the LED light up? It is because an LED is a diode symbol. Notice that we had to bend the lines in the schematic to put the GND at the top and the 5V at the bottom. This is because (as mentioned previously) it is conventional to put the higher voltage symbol above the ground symbol.



■ **FIGURE 28:** ***LED + resistor schematic.***



■ **FIGURE 29:** ***Reversing 5V and GND.***

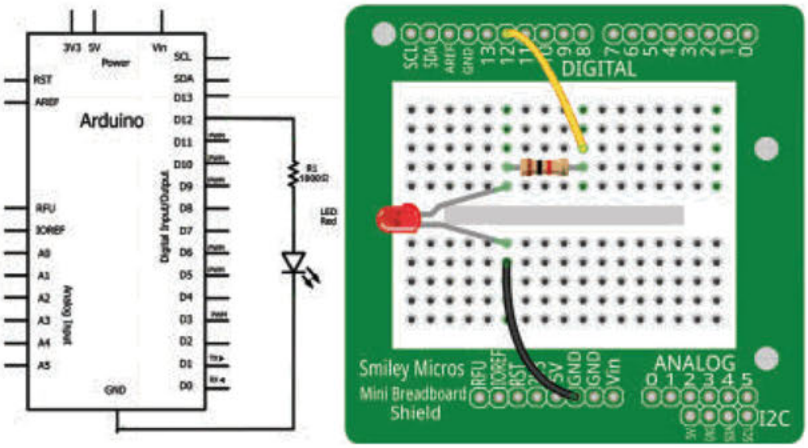
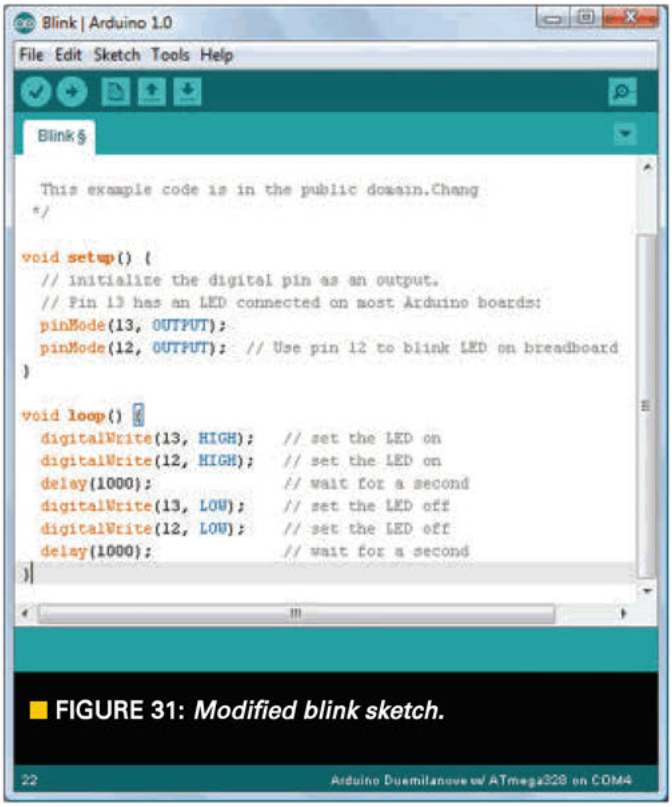


FIGURE 30: *LED on pin 12 circuit.*


Blink | Arduino 1.0
File Edit Sketch Tools Help
Blink §
22
Arduino Duemilanove w/ ATmega328 on COM4

```
 This example code is in the public domain.Chang
 */

void setup() {
  // initialize the digital pin as an output.
  // Pin 13 has an LED connected on most Arduino boards:
  pinMode(13, OUTPUT);
  pinMode(12, OUTPUT);  // Use pin 12 to blink LED on breadboard
}

void loop() {
  digitalWrite(13, HIGH);   // set the LED on
  digitalWrite(12, HIGH);   // set the LED on
  delay(1000);              // wait for a second
  digitalWrite(13, LOW);    // set the LED off
  digitalWrite(12, LOW);    // set the LED off
  delay(1000);              // wait for a second
}
```

FIGURE 31: *Modified blink sketch.*

Lab 3: How to Use an LED – Digital.

Now that we know how to light up an LED with current supplied by our five volt source, let's apply that to using an Arduino digital output pin to supply five volts or zero volts to turn the LED on and off. We saw in Chapter 1 Lab 4 last month how to write and run a simple program that blinks the pin 13 LED. In this lab, we will put an LED on the breadboard and make it blink using pin 12.

Required tools:

1 Arduino
1 Proto shield

Estimated time for this lab: 30 minutes

Parts Required:

1 Red LEDs
1 1,000Ω resistor
2 Jumper wires

Check off when complete:

❑ Make sure the power is off before building the circuit.
❑ Hook up the wire to pin 12 and ground as shown in **Figure 30**.
❑ Plug the USB cable into the Arduino.
❑ Open the Arduino IDE and File/Examples /Basic/Blink like you did for Lab 2.
❑ Change the code to add the pin 12 controlled LED as follows:

```
void setup() {
  // initialize the digital pin as an output.
  // Pin 13 has an LED connected on most Arduino
  // boards:
  pinMode(13, OUTPUT);
  pinMode(12, OUTPUT);// Use pin 12 to blink LED
                      // on breadboard
}

void loop() {
  digitalWrite(13, HIGH);   // set the LED on
  digitalWrite(12, HIGH);   // set the LED on
  delay(1000);              // wait for a second
  digitalWrite(13, LOW);    // set the LED off
  digitalWrite(12, LOW);    // set the LED off
  delay(1000);              // wait for a second
}
```

❑ Note that the *delay(1000)* causes a 1,000 millisecond (one second) delay.
❑ Following the methods you learned last month, verify and upload the program to your Arduino.
❑ Does the LED on the breadboard blink?

- Yes: Great! You are ready to move on.
- No: Looks like you'll need to do some debugging. *Does the pin 13 LED on the Arduino blink?*
- No: You've probably wired the circuit wrong on the breadboard. Carefully check your wiring.
- No: You've probably entered something wrong in the code or not uploaded it properly. Carefully check that the code is exactly as shown and try verifying and uploading it again.

Next Month

In Arduino 101 Chapter 3, we will begin learning how an Arduino program works. **NV**

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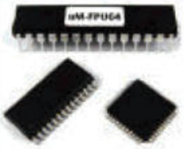

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>>> QUESTIONS

Traffic Detector

I live in the country on a side road that tee's into a busy arterial. The arterial curves sharply to the left, offering only about 100 feet of visibility. Most of my trips involve turning left, thus crossing one lane of oncoming traffic. A car coming around the curve at 60 MPH gives me a little over one second reaction time when it first becomes visible.

At night, I can see oncoming headlights reflecting off a guardrail which gives me plenty of warning. During the day, I roll down my window and listen. However, this is not the best method with my aging hearing. I'm looking for a clever electronic solution to detect approaching cars and provide an earlier warning.

There is a pole on the other side of the road about 75 feet away that could be used to mount a device to bounce a signal off of. I'm new to electronics but if "steered" in a useful direction I can do the research and make it work. Any ideas?

#2141 **Curtis Erpelding**
Port Orchard, WA

Laser Cutter To 3D Printer

I want to move from a mill to a 3D printer to fabricate parts for my projects. As far as printing materials go, I've heard that regular plastic is toxic and print quality is poor, and that the PLA alternative is brittle and heavy. What's the best printing material out there? Are there better choices?

#2142 **Alec Litmar**
via email

>>> ANSWERS

[#12131 - December 2013]
Accelerometer Versus Gyroscope

I'm working on a robot project that requires navigation and I'm trying to decide between an accelerometer and a gyroscope chip. Accelerometers are cheaper, but I've heard not as accurate. Is this true? When should I use one over the other?

They are two different sensors. A gyro measures rotation about an axis. An accelerometer measures acceleration in a given direction. To create a true inertial navigation system, one needs to accumulate both acceleration and rotation information in all three axes (x, y, and z). An accelerometer can be used to make a rotation measurement. It will not be as accurate as traditional rotation sensors.

Nevertheless, for making "guidance" sensors as opposed to "navigation" sensors, there are many (relatively) inexpensive three-axis monolithic sensors based on MEMs accelerometers. Guidance is used to provide orientation feedback whereas a navigation sensor is used to place location after so many seconds, hours, or days.

For further study on the differences, look at the physics behind a ring laser or fiber optic gyro (it only takes a few minutes to figure out what is going on). The difference in what the sensors are measuring becomes apparent (**http://en.wikipedia.org/wiki/Ring_laser_gyroscope**).

D Ferguson
Austin, TX

[#12132 - December 2013]
Battery Dilemma

I use one of those headlamps a lot and replacing the batteries is getting expensive. Are there affordable rechargeable batteries that provide the same burn time as single use batteries?

Are there ever! Rechargeable 3.2V Lithium Iron Phosphate (LiFePO4) cells are surely the answer. They're powerful but safe, very lightweight, and available in both AA and AAA sizes at ~US$5 each.

Perhaps best of all is that one will replace two 1.5V alkalines (or three NiMH!).

Simple placeholding dummy cells can pad out the battery bay. I've taken to using these in my Canon digital cameras to great effect.

Stan Swan
Wellington, NZ

[#12133 - December 2013]
Explosive Potential

I want to encapsulate a circuit board with a small Li-Ion battery in epoxy for an outdoor weatherproof project. Does anyone have experience encapsulating batteries? Is this a good idea?

Epoxy encapsulation is pretty drastic. Why not simply seal things in a plastic screw top container?! If the explosive nature of Li-Ion cells is the concern, then you may be better off using the far more tolerant 3.2V rechargeable LiFePO4 (Lithium Iron Phosphate) version.

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Always use common sense and good judgment!

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AA/AAA sized LiFePO4 cells sell for ~US$5 each and are stated as good for 1,000s of charge/discharge cycles too. See **www.instructables.com/id/Single-AA-LiFePo4-cell-powered-project-in-a-parti/**.

Stan Swan
Wellington, NZ

[#1141 - January 2014]
Amplifier Hum

I picked up a "hum blocker" for my guitar amp, only to discover that all it does is disconnect the ground from a three-prong outlet.

It seems to work, but is it safe to use?

#1 Safe is a relative matter of degree. The safety ground wire in a standard three-wire AC cord is there for a reason. However, the NEC does allow for devices that do not have that safety ground connection. Many electric and electronic devices are made without it.

The safety ground connection is there to insure that the fuse does blow or the circuit breaker does trip if a conductive outer case of the device becomes electrified. The current that flows from the hot wire to the safety ground blows the fuse or trips the breaker and then there is no danger of shock.

Devices that do not have that safety ground usually employ a double insulation method to prevent such a short to the outer case or to the user. Thus, if there is internal insulation AND the outer case is an insulating material like plastic, then TWO different insulators would have to fail for the user to get shocked.

Older devices — like early electric lamps — were made with metal outer cases and often the electric wires inside them were only a small fraction of an inch from that conductive case. Older electric cords were insulated with real rubber which deteriorated over time and became "frayed." The cardboard insulators in lamp sockets literally fell apart after some years of service, usually with over-sized bulbs in the lamp (rated at 40W so the user put a 60W or a 100W for more light). Etc., etc., etc.

It is not possible to tell if a particular device (like your amplifier) is safe without examining it. If it was commercially manufactured in the US or imported properly, then chances are it is okay. Things like the UL (Underwriter's Laboratories) tag are supposed to tell the consumer that it has been inspected and found to comply with the code. If it is a kit or was made in someone's kitchen or garage, then it may or may not be okay.

Hum like this is usually a result of what is called a "ground loop." Both the signal cable between the audio devices and the power cables to them are grounded, and they form two different and distinct ground paths between them. If there is any 60 Hz current flowing in either of them, then the circuit/signal ground planes in each of those devices will be at a different AC potential and the hum is introduced into the signal.

One way of eliminating this situation is to cut the safety ground on one or both of the devices, but this eliminates the safety feature of that connection. A better way to eliminate this situation is to use a balanced audio line between the devices and to connect (ground) the shield only at the source end of that line. In this way, there is only one ground connection between them via the AC power. Many times this is used in professional audio installations where long lines must be run. This may not be possible on amateur equipment where single ended audio lines are often run.

Another solution is to use a differential input amplifier at the receiving end of the audio line. This can be accomplished with a transformer or with actual active circuitry. With a transformer, the center lead and the shield of the single ended cable are connected to the primary of the transformer so the shield is not connected to the chassis/signal ground of the amp.

Active circuitry with a balanced input is more complicated. I am designing such an amp at the present time to overcome a noise problem between my audio/visual equipment cabinet behind my chair and the computer on the desk in front of it. Due to the arrangement of the room, I had to run a 50 foot cable and it does pick up hum.

An audio transformer of sufficient low frequency response would cost a bundle. Since the audio is single ended (not balanced), this may be the only solution. I have searched and could not find a reasonably priced differential input audio amp for this application. Professional ones seem to start in the hundreds and go up from there.

Another factor that helps to overcome noise and hum is the impedance of the audio line. A lot of amateur equipment uses a high line impedance which may be okay for a few feet, but longer high impedance (10 kohms) lines will pick up noise and hum from the environment. Professional audio uses lower impedance lines to overcome this.

The old standard was 600 ohms, but modern equipment often has extremely low output impedance (one ohm or less) and a higher input impedance. This works in most situations. When long lines need lower termination impedance on the receiving end, a simple resistor can be connected across the line at that point.

Paul Alciatore
Beaumont, TX

#2 Some comments and concerns regarding your question. First, I am not clear if this is a repair or a retrofit. I would also presume this is a tube-type amplifier, since they were often built with point-to-point wiring and hum pickup was highly likely with so many signal wires running around the chassis.

I would presume that either this is a retrofit or the original noise filter cap was removed in the past. The fact that adding the new cap from line to ground reduced the 60 cycle hum (or 120, depending on the rectifier design), it seems that this might actually be a repair.

Or, the filter caps themselves are old and leaky, so you are aiding them but not actually curing the problem. If the amp is old, it often needs to have the filter caps replaced and (sometimes) some interstage decoupling caps as well.

With that background, I caution that this involves principles of safety and if you are not experienced with working on mains circuits, this effort would be best left to a professional. Just because something works does not mean it is well-executed or robust.

Since guitar amps get moved, jostled, banged around, and are often not treated caringly, there is a chance your soldered connections of this component could break loose without your knowledge and you could have a real shock hazard on your hands.

Okay, assuming all that is well-appreciated, the type of cap you use is critical. This component is connecting one side of the AC mains to the accessible chassis. You cannot assume that a ground pin on a cord will save your life since you have no idea how well the ground-to-neutral impedance is controlled in the building's branch circuit you just plugged into.

Hence, the cap itself must be suitably rated to be connected from line to ground. Therefore, this must be a Y2 type of cap.

If you have no idea what a Y2 cap is, then read this link first: **www.justradios.com/safetytips.html**. There are many good manufacturers of Y2 caps (Vishay, KEMET, Panasonic, etc.). Here is a good selection from Mouser: **www.mouser.com/new/Kemet-Electronics/KEMET_XY_Film_Caps**.

Be sure that you do not rely on solder for mechanical support of live parts. Always wrap the cap leads snugly around the terminals it is connecting to and check to determine that it would tend to stay there if no solder was used. Solder is not meant for mechanical retention of massive parts. Once you feel it is well mounted, then use solder to make the electrical connection to the terminals.

Jon Kalfus
Red Bank, NJ

[#1142 - January 2014]
Which Way Should I Go?

I'm new to electronics, recently retired, and in need of some direction. Should I spend my time learning about resistors, capacitors, and transistors, or start with an Arduino or other microcontroller?

#1 In answer to your question — Yes, you should learn about electronics fundamentals along with learning about microprocessors. You need to have an understanding of the basics, however, you do not need to get a degree in electrical engineering.

Your best bet is to check out your local library and see if they have any books dealing with electronics fundamentals. You may want to see if they have a copy of the *ARRL Amateur Radio Handbook*. They also have a book titled *Understanding Basic Electronics* which will help you get started.

I don't know whether or not you have your ham license but you may want to see if there is an amateur radio club in your area and get your self an "Elmer," which is ham radio talk for a mentor, as most hams that I know of are willing to pass on the knowledge they have acquired.

There are also several groups on Yahoo! devoted to beginners which are worth joining.

Craig Kielhofer
Des Moines, IA

#2 Starting learning electronics with discrete components (resistors, capacitors, diodes, etc.) or micros is a good question. Fortunately, you can choose to start with either and be successful due to modern kits and the Internet. If you are "into" programming in C language, microcontrollers would be a good place to start.

To begin in the microcontroller field, I would start with the BASIC Stamp. Parallax (**www.parallax.com**) has some good starter kits which supply the microcontroller, breadboard, and other components to perform the experiments they have well documented in the enclosed manual. After gaining proficiency with the Stamp, you can move up to the Arduino (**http://makerzone.mathworks.com/arduino**) or the Propeller (**www.parallax.com**). *Nuts & Volts* has projects every month on microcontroller type systems which can also be used to further your self-training.

If you don't feel comfortable with programming, learning the basics of electronics may be the place to start. Googling "electronics tutorials" will show you a number of FREE websites which offer electronics training for beginners. (Also, the *Nuts & Volts* Webstore sells books and kits to help you learn electronics.)

Electronics is a neat field to study. It is not easy. It is not for everyone. However, for anyone who is looking for a challenge, electronics is the place to be. Whether you start with basic components or microcontrollers, you will eventually see the need to learn about the other field.

Microcontrollers use basic electronic components to function as a system, and often it is advantageous to replace a "kludge" of electronic components with a microcontroller app.

Tim Brown PhD EE, PE
via email

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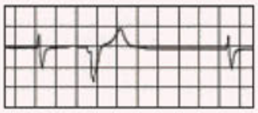
One of our engineers/guinea pigs, checking his heart!



Look what I found!

The documentation with the ECG1C covers everything from the circuit description of the kit to the circuit description of the heart! Multiple "beat" indicators include a bright front panel LED that flashes with the actions of the heart along with an adjustable level audio speaker output that supports both mono and stereo hookups. In addition, a monitor output is provided to connect to any standard oscilloscope to view the traditional style ECG/EKG waveforms just like you see in a real ER or on one of the medical TV shows! See the display to the right? That was me, when I noticed some skipped beats in my pulse! An immediate cardiac check found I had Trigeminy, or PVCs that occur at intervals of 2 normal beats to one PVC! And I saw it with our ECG1 kit!

The fully adjustable gain control on the front panel allows the user to custom tune the differential signal picked up by the probes giving you a perfect reading and display every time! 10 hospital grade re-usable probe patches are included together with the matching custom case set shown. Additional patches are available in 10-packs. Operates on a standard 9VDC battery (not included) for safe and simple operation. Note, while the ECG1C professionally monitors and displays your heart rhythms and functions, it is intended for hobbyist usage only. If you experience any cardiac symptoms, seek proper medical help immediately!

ECG1C	**Electrocardiogram Heart Monitor Kit With Case & Patches**	**$44.95**
ECG1WT	**Electrocardiogram Heart Monitor, Factory Assembled & Tested**	**$89.95**
ECGP10	**Electrocardiogram Re-Usable Probe Patches, 10-Pack**	**$4.95**

Electronic Love Tester

✔ **10 LED love scale display!**
✔ **Audible love level sound!**
✔ **Great party fun!**
✔ **Heart shaped PC board!**

This uniquely shaped "Love Tester" is the ultimate gag for any couple! Designed to check your love life, each partner holds one end of the tester PCB at the appropriate male and female touch pads. Then they romantically join hands and watch the results on the love meter! 10 green, yellow, and red LEDs act like a scale, and just like the carnival, when it hits the top they flash, indicating you're a red hot couple! There is also an audible alarm that changes with the "love level". Next time the party isn't going anywhere, bring this out, it's a riot! Compatible with all couples! Runs on a standard 9V battery (not included)

MK149	**Electronic Love Tester Kit**	**$16.95**

LED Magic Wand

✔ **Message floats in air!**
✔ **Fun at concerts & events!**
✔ **High visibility red LEDs**
✔ **Pre-programmed or custom messages**

Use the "Magic Wand" to display your true feelings! Simply shake it back and forth and brilliant messages seem to appear in mid-air! Six high intensity LEDs are microprocessor controlled to display messages and graphics that are pre-programmed into the wand. You can also custom program a message of your choice! From amazing your friends, making a statement at a concert, or simply telling your loved one how you feel, the message wand can't be beat! Runs on two AAA batteries (not included), and features auto power-off.

MK155	**LED Magic Wand Kit**	**$17.95**

LED Flashing Heart

✔ **28 brilliant red LEDs!**
✔ **Unique dual heart design!**
✔ **Freestanding mount!**

What a way to display your feelings to that very special person in your life! Get out your soldering iron and dazzle her with this unique dual heart electronic display that you can say you built yourself!

28 brilliant red LEDs are formed into two separate heart designs on the heart shaped PC board creating a great flashing display that's easy to assemble. Built-in battery holder base makes the sweetheart freestanding and perfect for a desk or table. Runs on a standard 9V battery (not included). Measures 2.4" x 2.4" x 1.2".

MK101	**LED Flashing Sweetheart Kit**	**$6.95**

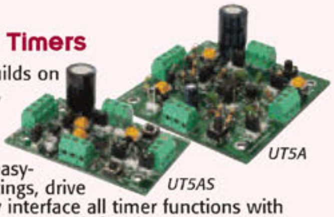
SMT LED Heart Display

✔ **Alternating flashing!**
✔ **6 super bright SMT LEDs!**
✔ **Learn all about SMT!**
✔ **Definitely gets her attention!**

This cute little kit gives you a distinctive red display using 6 Surface Mount (SMT) LEDs. The PC board is in the shape of a red heart. The small size makes it perfect to be used as a badge or hanging pendant around your neck. Even better as an illuminated attention-getting heart to accompany a Valentines Day card! Makes a great SMT learning kit to bring you into the world of SMT technology, design, and hands-on soldering and troubleshooting. Don't worry, extra SMT parts are included just in case you lose or damage any! Runs on a small CR2025/32button cell (not included). Measures 1.9" x 1.7" x .3".

MK144	**SMT Flashing Heart Kit**	**$11.95**

Ultimate 555 Timers



This new series builds on the classic UT5 kit, but takes it to a whole new level! You can configure it on the fly with easy-to-use jumper settings, drive relays, and directly interface all timer functions with onboard controls or external signals.

All connections are easily made though terminal blocks. Plus, we've replaced the ceramic capacitor of other timer kits with a Mylar capacitor which keeps your timings stable over a much wider range of voltages! Available in through hole or surface mount versions! Visit www.ramseykits.com for version details.

UT5A	**Through Hole 555 Timer/Osc Kit**	**$21.95**
UT5AS	**SMT 555 Timer/Osc Kit**	**$29.95**

USB PIC Programmer

Finally, a compact USB PIC Programmer with a 20 pin ZIF socket for easy programming of most Microchip PIC Flash devices that does not require low voltage programming. Plus it uses USB, therefore no more RS232 compatibility blues!

CK1301	**USB PIC Programmer Kit**	**$34.95**

Doppler Direction Finder

Track down jammers and hidden transmitters with ease! 22.5 degree bearing indicator with adjustable damping, phase inversion, scan and more. Includes 5 piece antenna kit. Runs on 12VDC vehicle or battery power.

DDF1	**Doppler Direction Finder Kit**	**$169.95**

Digital Recorder/Player

This little board records and plays back up to 8 minutes of audio! Features a on-board electret mic as well as line input and output and speaker output! Adjustable sample rate to match your application. Runs on 9-12VDC.

K8094	**Audio Storage Module Kit**	**$32.95**

HV Plasma Generator

Generate 2" sparks to a handheld screwdriver! Light fluorescent tubes without wires! This plasma generator creates up to 25kV at 20kHz from a solid state circuit! Build plasma bulbs from regular bulbs and more! Runs on 16VAC or 5-24VDC.

PG13	**HV Plasma Generator Kit**	**$64.95**

Speedy Speed Radar Gun

Our famous *Speedy* radar gun teaches you doppler effect the fun way! Digital readout displays in MPH, KPH, or FPS. You supply two coffee cans! Runs on 12VDC or our AC121 supply.

SG7	**Speed Radar Gun Kit**	**$74.95**

Tickle-Stick Shocker

The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light and an unlabeled switch! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC.

TS4	**Tickle Stick Shocker Kit**	**$9.95**

Van de Graaff Generators

Create your own lightning with these time tested student favorites! Produces low current static currents that can be "shocking" but perfectly safe! Draw sparks to a screwdriver, grab hold and watch your hair stand straight up! Two models produce from 200kV to 400kV!

VG	**Van de Graaff Generators**	**from $139.95**

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Stereo Audio Gain Controller

NEW!

Your Audio Engineer!

- ✔ **Stereo audio processing while preserving audio dynamics!**
- ✔ **True stereo control keeps virtual sonic source location intact!**
- ✔ **Auto-bypass restores original levels when power is turned off!**
- ✔ **Built-in bar graph indication of signal level with display mute!**

The SGC1 is one of our latest kits, and provides a great solution to the age-old problem: how can we easily correct inconsistent audio levels without negatively affecting the dynamics of the audio signal? The SGC1 circuit implements a principle known as the "Platform Gain Principle," which was originally developed by CBS Labs (what we now know as CBS in the TV and radio world) to allow transmitted audio levels to be automatically adjusted to keep them within a desired range.

Think of it like an audio engineer, constantly adjusting the output level in order to limit highs that would be too loud while boosting lower levels so that they can still be heard. You may think "oh, this is just another limiter/compressor!" Not so! Here's the real trick: keeping the full dynamic range ratio of the output signal the same as the original input - something the typical limiter/compressor can only dream of doing! The SGC1 can be placed in just about any standard analog stereo line level audio circuit (the red and white RCA connectors or the mini-phone connector) to keep the audio level within the desired range. It's also the perfect addition to any of our hobby kit transmitters, allowing you to match levels between different audio sources while keeping lows audible and preventing the highs from overdriving. The SGC1 makes a great addition to any audio system where you need to keep levels from different sources under control, but still make sure they all sound great! In addition to its useful basic function and great audio performance, the SGC1 also boasts a front panel LED meter to give an indication of the relative level of the input signal, plus a level control (also on the front panel) that allows you to adjust the controller to the min/max center point of your desired level range. And yes, it is a ***Stereo Gain Controller!*** Meaning that the levels of both the left and right channels are monitored and adjusted equally, thereby maintaining the relative virtual position of things like instruments, singers and speakers! The entire unit is housed in a slim attractive black textured aluminum case that is sure to complement your studio or home theatre. If you're looking for perfect audio levels, hire a broadcast audio engineer, but if that doesn't fit your budget, the SGC1 is the next best thing! Includes 15VDC world-wide power adapter.

SGC1	**Stereo Audio Platform Gain Controller Kit**	**$179.95**

4-Channel USB Relay Control

This professional quality USB relay controller and data acquisition module allows computer controlled switching of external devices, plus full bi-directional communication with the external world using the USB port of your computer. It is compatible with both Windows and Apple OS X, as well as various Linux flavors. When you plug it into your computer, it appears as a USB CDC device that creates a Virtual Serial (COM) port allowing easy communication with the board through any programming language that supports serial communications (VB, VB.NET, C#, C, C++, Perl, Java, etc).

The controller features four onboard relay outputs with a current rating of 10A each. Also onboard is a 6-channel Input/Output interface, with each channel individually configurable as Digital Input, Digital Output, Analog Input (10-bit Resolution), or DS18B20 series Temperature Sensor. In Digital Input/Output modes, each channel can support a TTL compatible or ST input or a 5V output signal. In Analog Input mode, each channel can convert a voltage of between 0 to 5V into a 10-bit digital representation. Finally, in Temperature Sensor mode, each channel can be connected to a DS18B20 series Digital Temp Sensor.

UK1104	**4-Ch USB Relay Interface Kit**	**$59.95**

8-Channel Remote Ethernet Controller

Now you can easily control and monitor up to 8 separate circuits via the standard Ethernet network in your home or office. Connection wise it couldn't be simpler. The controller functions as an IP based web server, so it can be controlled by any internet browser that can reach your network! There are no drivers or proprietary software required, just access the controller like any web page from your PC, laptop, or even your smartphone!

Security is assured allowing up to 4 separate user credentials. The controller can be set to a specific static IP within your network subnet or can be set to DHCP (auto negotiate). The controller can even be programmed to send you an email to notify and confirm power up and status changes!

To simplify the connection of your equipment to the controller, 8 separate and isolated relay outputs are provided! This gives you internet or network control of up to 8 separate functions. No need to worry about interfacing a logic high or logic low, or burning up the interface! The applications are endless! From something as simple as turning on and monitoring lights at your house with a normal latched closure to advanced control of your electronic gadgets, radio equipment, or even your garage door!

Each relay contact is rated at 12A at 30VDC or 16A at 230VAC. Each of the 8 channels has built-in timer and scheduler programs for day, weekend, working days, every day, and every day except Sunday. Relay control functions are programmable for on, off, or pulse (1-99 seconds, 1-99 minutes, or 1-99 hours). In addition to control functions, the web interface also displays and confirms the status of each channel. Each channel can be custom labeled to your specific function name. The controller operates on 12VDC or 12VAC at 500mA or our new AC121 global 12VDC switching power supply below. Factory assembled, tested, and ready to go! Even includes a Cat-5 cable!

VM201	**8-Channel Remote Ethernet Controller, Factory Assembled & Tested**	**$169.95**

Air Blasting Ion Generator

Generates negative ions along with a hefty blast of fresh air, all without any noise! The steady state DC voltage generates 7.5kV DC negative at 400uA, and that's LOTS of ions! Includes 7 wind tubes for max air! Runs on 12-15VDC.

IG7	**Ion Generator Kit**	**$64.95**

Broadband RF Preamp

Need to "perk-up" your counter or other equipment to read weak signals? This preamp has low noise and yet provides 25dB gain from 1MHz to well over 1GHz. Output can reach 100mW! Runs on 12 volts AC or DC or the included 110VAC PS. Assmb.

PR2	**Broadband RF Preamp**	**$69.95**

Tri-Field Meter Kit

THE GHOST DETECTOR!

"See" electrical, magnetic, and RF fields as a graphical LED display on the front panel! Use it to detect these fields in your house, find RF sources, you name it. Featured on CBS's Ghost Whisperer to detect the presence of ghosts! Req's 4 AAA batteries.

TFM3C	**Tri-Field Meter Kit**	**$74.95**

Passive Aircraft Receiver

The hit of the decade! Our patented receiver hears the entire aircraft band without any tuning! Passive design has no LO, therefore can be used on board aircraft! Perfect for airshows, hears the active traffic as it happens! Available kit or factory assembled.

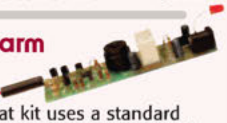
ABM1	**Passive Aircraft Receiver Kit**	**$89.95**

Electret Condenser Mic

This extremely sensitive 3/8" mic has a built-in FET preamplifier! It's a great replacement mic, or a perfect answer to add a mic to your project. Powered by 3-15VDC, and we even include coupling cap and a current limiting resistor! Extremely popular!

MC1	**Mini Electret Condenser Mic Kit**	**$3.95**

Laser Trip Sensor Alarm



True laser protects over 500 yards! At last within the reach of the hobbyist, this neat kit uses a standard laser pointer (included) to provide both audible and visual alert of a broken path. 5A relay makes it simple to interface! Breakaway board to separate sections.

LTS1	**Laser Trip Sensor Alarm Kit**	**$29.95**

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- ✔ **130, 200, 300, & 500 in one labs!**
- ✔ **Practical through hole and SMT soldering labs!**
- ✔ **Integrated circuit AM/FM radio lab!**
- ✔ **Super comprehensive training manuals!**

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If you are looking to either learn or hone up on your through hole or SMT soldering skills check our SP1A and SM200K Practical Soldering Labs. You will be a soldering master in no time!

We make it easy to learn IC's while at the same time, building a neat AM/FM radio with our AMFM108K AM/FM IC lab kit. You will have a blast AND learn!

PL130A	**130-In-One Lab Kit**	**$39.95**
PL200	**200-In-One Lab Kit**	**$84.95**
PL300	**300-In-One Lab Kit**	**$109.95**
PL500	**500-In-One Lab Kit**	**$249.95**
SP1A	**Through Hold Soldering Lab**	**$9.95**
SM200K	**SMT Practical Soldering Lab**	**$22.95**
AMFM108K	**AM/FM IC Lab Kit & Course**	**$36.95**

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